THE BOOK WAS DRENCHED

THE INDIAN SUGAR INDUSTRY

BY

KHAN BAHADUR S. M. HADI

DIRECTOR OF AGRICULTURE,

BHOPAL STATE.

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AND PUBLISHED BY KHAN BAHADUR S. M. HADI DIRECTOR OF AGRICULTURE, BHOPAL STATE.

DEDICATION.

THIS BOOK IS RESPECTFULLY DEDICATED

TO

HIS HIGHNESS NAWAB SIKANDAR SAULAT,
IFTIKHAR-UL-MULK, HAJI
SIR MOHAMMAD HAMIDULLAH KHAN BAHADUR,
B.A., G.C.I.E., C.S.I., C.V.O.,

RULER OF BHOPAL,

as a token of esteem and admiration

for

His Highness' keen interest

in the

development of Indian Industries,

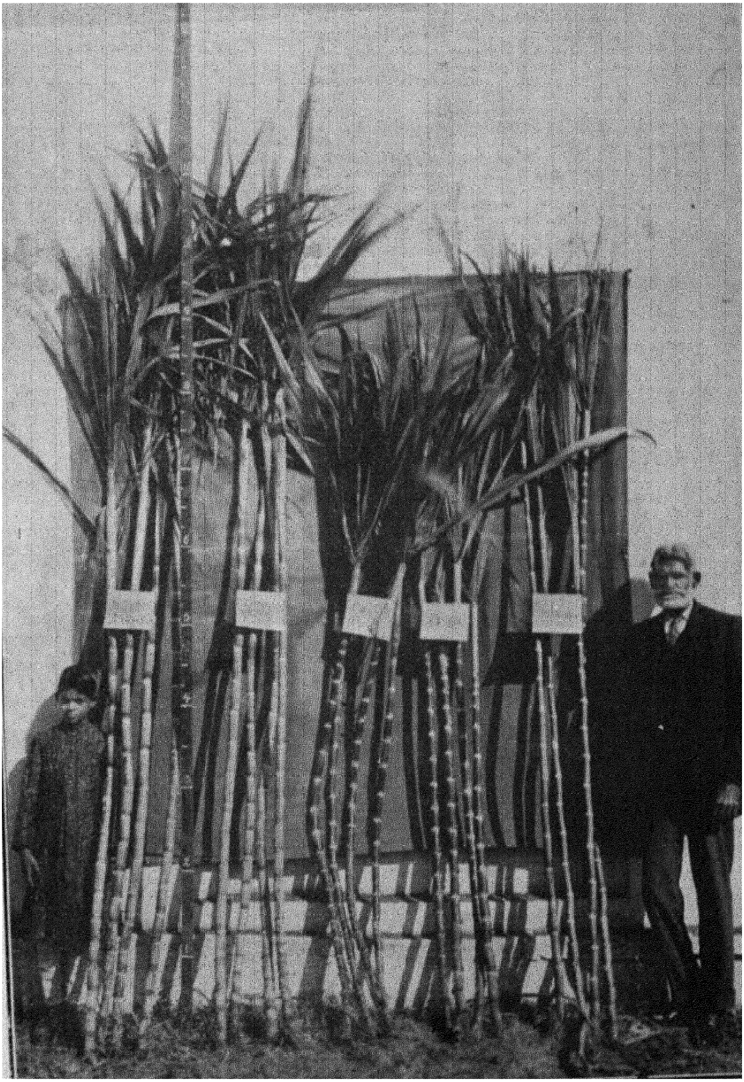
by His Highness' devoted servant,

THE AUTHOR.

BHOPAL.
The 15th June, 1929

PHOTO
No. 1.

SUGARCANE VARIETIES
GROWN AT BHOPAL FARMS.



WHITE TRANSPARENT   MANJAV   208.B   D.109   WHITE DE[illegible] PAUNDA

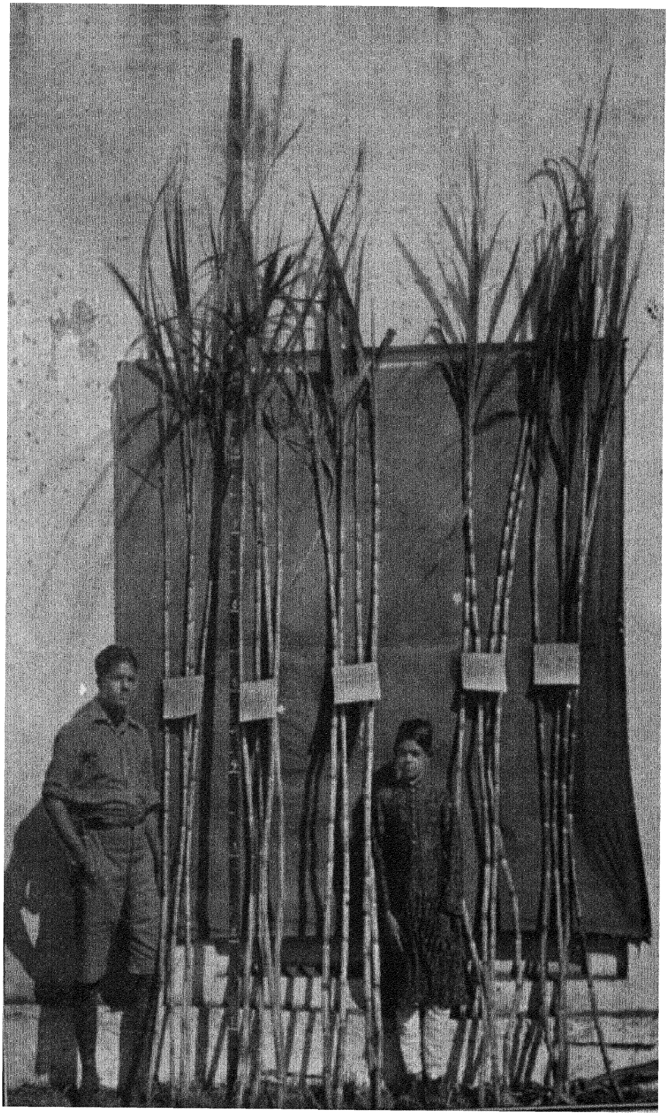
PHOTO
No. 2.

SUGARCANE VARIETIES
GROWN AT BHOPAL

S. 48 [illegible] [illegible] LEDI DHAUL
KHADIA TORA OR
BHELSANI.

Photo No. 3.

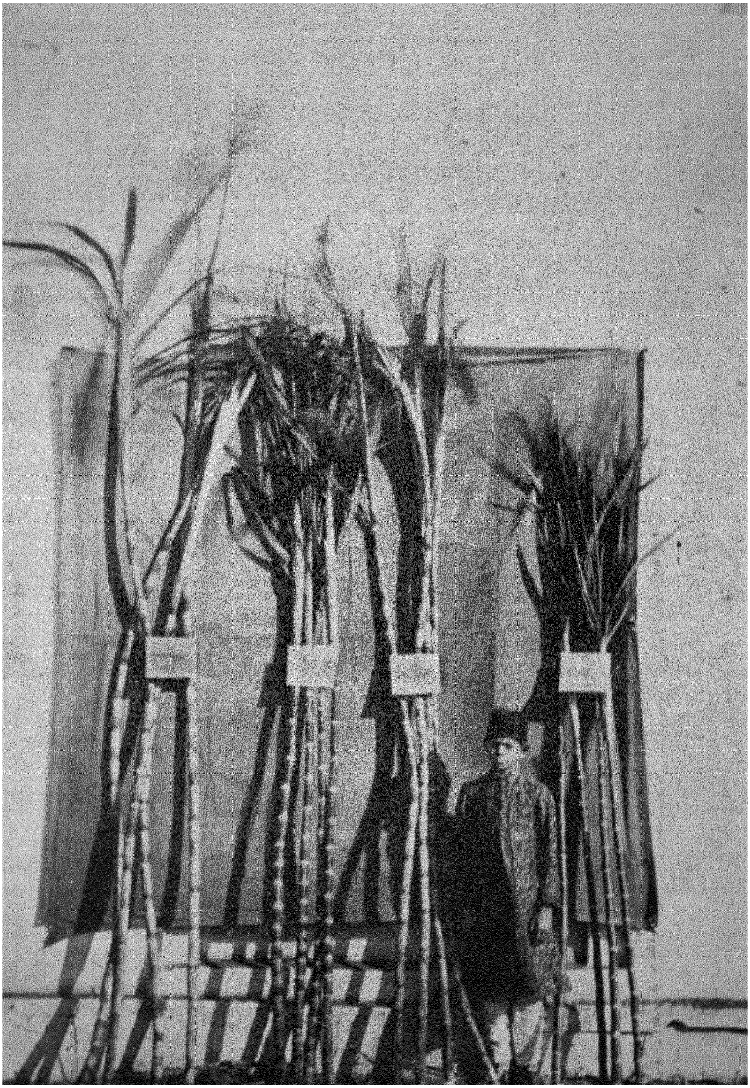
SUGARCANE VARIETIES GROWN AT BHOPAL FARMS.



Co. 205. Co. 210. Co. 213. Co. 221. Co. 281.

PHOTO
No. 4.

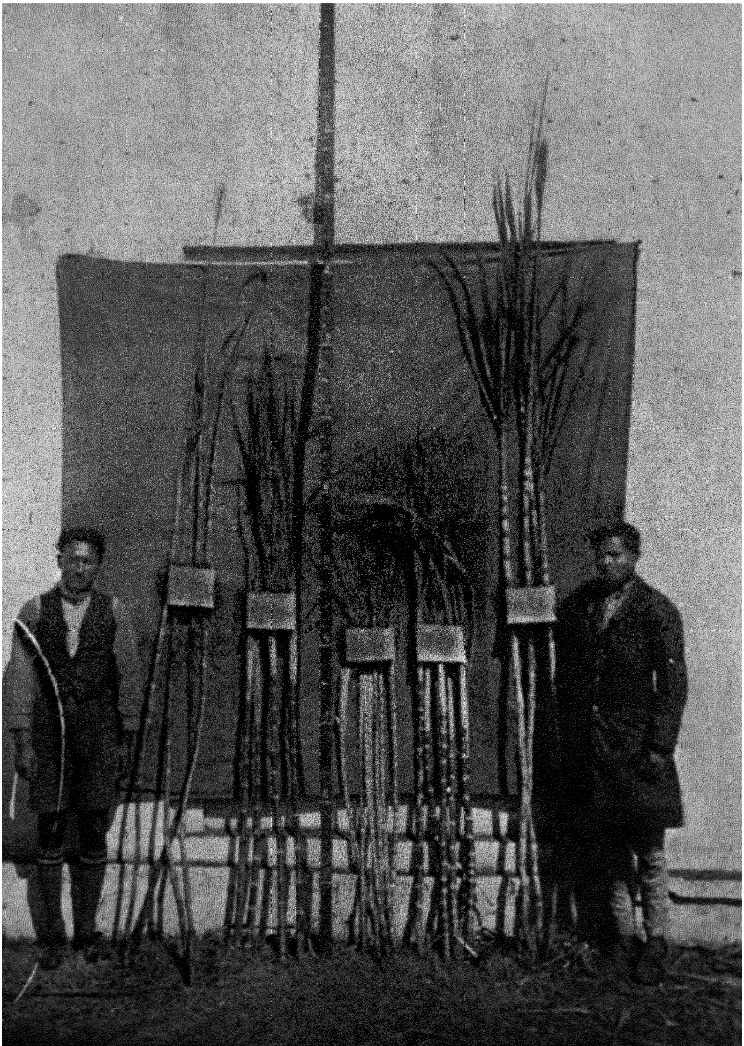
SUGARCANE VARIETIES
GROWN AT BHOPAL FARMS.



P.O. J. 33. (LAKHAPUR) | 247 B. | WAXY RED | RED MAURITIUS.

PHOTO
No. 5.

SUGARCANE VARIETIES
GROWN AT BHOPAL FARMS.



Co. 214 — STRIPED MAURITIUS — A. 42 — PATTA PATTI (RATOON) — Co. 221

INTRODUCTION.

Summary of operations and results.

About the middle of the 16th century, Faizi, the renowned Minister of Akbar, while reporting from Khandesh on the experiences of his travels, *wrote, with reference to the agricultural and economic aspects of Malwa, in eulogistic terms in his characteristically oriental style as follows:—

"No pen is capable of praising sufficiently the Vilayet (Province) of Malwa, which abounds in natural streams, flowing like virtuous sentiments from the hearts of the pious. All its lands are normally suitable for agriculture, some of them belonging to that eminent class, which is fit to grow sugarcane without the people giving irrigation to the crop, and so saturated with moisture (fertile) that the percolation water can be got at within 5 yards of the surface."

In the same communication the distinguished Minister, while referring specifically to the agricultural interest displayed by one of Akbar's Turkish officials stationed at Ujjain, whose name was Qazi Baba, remarked that that grandee "was the proud possessor of a sugarcane plantation deserving of high encomiums. Nowhere else in Malwa did sugarcane of equal nicety or delicacy of taste display its growth."

The author needs no apology in introducing himself to his readers, as an individual, who has had the privilege of seeing the vicissitudes of agricultural research for close on 20 years, and the best portion of whose life was spent, as an Agricultural Officer under the Government of United Provinces, in carrying on investigations in the cultivation of sugarcane, in making a classification of the existing varieties, and in devising improvements in the methods of manufacture of the various indigenous saccharine products. For official reasons, he had done very little agricultural work for nearly 10 years, when, on retirement from Government service in a different sphere of activity, he was appointed to take over the Department of Agriculture at Bhopal, under the immediate supervision of the late Heir-Apparent, Col. Nawab Sir Mohammad Nasrullah Khan Bahadur, K.C.S.I., whose untimely death has proved a serious loss to the Department. The author was requested to lay out a programme of remunerative agricultural experiments likely to prove beneficial to the ryots of Bhopal. In compliance with the request, a programme of intensive agriculture was prepared, in which the sugarcane crop occupied the most prominent place. In choosing the sugarcane as the principal crop, the author was actuated, on the one hand by

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***Darbar-i-Akbari** by Syed Mohammad Husain Âzád, page 400.

the above remarks of Akbar's great minister, and on the other, by the admirable results obtained by the Government Farms at Shahjahanpur (U.P.), Manjri, near Poona (Bombay), and Coimbatore (Madras), from the cultural work which had formed the subject matter of several official publications. Besides, Her Highness the Ruler of Bhopal had remarked more than once that a British officer of considerable agricultural experience had visited the State 55 years ago, and pronounced that the soil and the climate of the State were pre-eminently suitable for the successful growth of sugarcane. Simultaneously, but quite independently of the author, Mr. A. Howard, C.I.E., the distinguished Botanist of the Pusa Agricultural Institute, was consulted by the Government of Bhopal, as to the lines on which the Agricultural experiments might most profitably be inaugurated in the State. It was a happy coincidence that Mr. Howard's scheme gave equally conspicuous prominence to the desirability of experimenting with intensive cultivation of varieties of sugarcane of established reputation, on the lines followed at Shahjahanpur and Manjri. Experiments were started on a very small scale in the growing season of 1922-23, at the Nuzhat Afza and Nabi Bagh Farms of Bhopal, with canes of S48, S39, Co214, Co221 and A42, kindly furnished by Mr. Geo. Clarke, F.I.C., F.C.S., C.I.E., Director of the U. P. Department of Agriculture.

Meanwhile the late Nawab Mohsinulmulk, General Obaidullah Khan Bahadur, C.S.I., whose interest in promoting the cause of remunerative agriculture knew no bounds, conceived the idea, without any reference to the author, of establishing a large sugar plantation at Sewanian, six miles south of Bhopal. This idea he quickly carried into effect. A power plant for irrigation was set up within a few weeks, the necessary drains and water channels were dug with the least possible delay, and the land was cultivated deep with an American tractor. A power crusher, the Chattanooga Mill of 12" horizontal rollers, workable with the engine of the tractor, was purchased later. The author was then consulted in regard to the selection of the kinds of canes likely to prove suitable, and he recommended the above named varieties, which were immediately procured for seed purposes from Shahjahanpur, through the courtesy of Mr. Clarke and his staff. P.O.J.33 (Lakhapur) had already been grown in Bhopal and was allowed to play a conspicuous part in the programme of cultivation at Sewanian. About 12 acres were planted with these varieties, and, in addition, 6 acres were planted with the indigenous canes, mainly Dhaul (the Agaul of U.P.), a medium cane with very low sucrose content. The method of cultivation perfected at Shahjahanpur Sugar Research Station, and published by the Department of Agriculture U. P., in the form of a pamphlet in 1919, was followed as closely as possible, under the immediate supervision of an experienced fieldman, whose services were secured

through the good offices of the Superintendent of that station. Manure was however used sparingly, as enough was not available. An excellent opportunity thus afforded itself of comparing the growth and sugar yield of the imported and local canes. Flourishing crops were produced, as good as have been seen anywhere in India. The imported canes all flowered profusely in the first year, and again in the following year, but neither the outturn nor its quality was affected adversely to any appreciable extent as a result of the flowering ("arrowing"). Unfortunately, for all concerned, the General became seriously ill just before the crushing season arrived, and the author was left to deal with the heavy standing crops. Recognising the enormous difficulty of converting this extensive area of cane into some form of raw sugar within the season, without and with no prospect of getting in time a set of pans as are used in Rohelkhand, with the defects of which the author was only too familiar, he set himself to the task of devising a modification of the Rohelkand **bel** which would be free from the said defects, with a number of small flat-bottomed pans which were available. The new **bel** was elaborated within a reasonably short time, and found, on trial, to serve as well for the manufacture of **gur** as for rab of a superior description. With pans much smaller in size and more easily manageable than the huge standard pans of Rohelkhand, the new **bel** boiled large quantities of **rab** during the day as efficiently (if not more) as is done by the larger and much heavier pans in Upper India, without, however, charring the sugar, and with appreciably less development of invert sugar. Where the same plant was worked to produce **gur,** the **gur** was admittedly better than the local product. The increasing illness of the General greatly handicapped the work, so that little more could be done than to ascertain the boiling capacity of the new **bel,** to determine the acreage outturn of one variety, viz P.O.J. 33, popularly known as Lakhapur (which amounted to over 85 Maunds of **rab** per acre), and to study the quality of the raw sugars yielded by the various canes. The General ultimately died, and the research work was dropped, so that a sugar scheme of immense potential value for Malwa was nipped in the bud, perhaps never to be taken up again on an equally ambitious scale except by the State's Agricultural Dept. However, the experience gained at Sewanian was utilised in the succeeding season, 1924-25, at the State Farm at Nuzhat Afza, where the same varieties of cane were intensively cultivated, with modifications in the Shahjahanpur system to suit local conditions, and with very little manure. Imported Shahjahanpur canes were also grown without irrigation, under a new system of preparing the ground and planting the sets, and, although the results are promising, especially so with S39, Co221 and Co213, they have not yet reached the stage when their publication would be justified. Soon after the cane crushing season commenced,

practical demonstrations were given at Nuzhat Afza in the manufacture of **gur** from the different varieties grown, both local and imported, and interested agriculturists of Bhopal were invited to have experiments in crop-cutting, the crushing of cane, and the boiling of juice done, under their own supervision, with the author's guidance. It was found that from 3 to 3½ tons, or more, of raw sugar of high grade was obtained per acre from the imported canes, especially S48, and Co221, as compared with 1 to 1½ tons from the local canes, combined with a smaller cost for cultivation and manufacture. In cultivation the cost of irrigation fell very considerably, six to seven waterings only during the season having proved sufficient for the imported varieties, as grown by the improved methods, against 25 to 30 or more waterings ordinarily given to local canes grown by the local methods. In manufacture the difference lay principally in the colour of the **gur** from the imported canes, which was most remarkably light, and in the sucrose contents, which varied from 72.80 to 82.82 against 60.07 to 65.59 p.c. found in the local specimens. Small boiling plants to correspond with the crushing capacity of one 3-roller and 2 three-roller mills, with a suitable furnace for each, were devised, with the specific purpose of producing high grade, light coloured **gur** or **rab, of a uniform quality throughout the working season.** Such a condition, so far as the author is aware, has not been achieved hitherto, either by the Indian cultivator or even by the professional boiler. The modified **bel,** which was intended mainly for the production of **rab,** on a commercial scale, was further tested and demonstrated, and a new arrangement provided to ensure the desired degree of clarification with such rapid concentration, that much greater quantity of juice could be dealt with, when available, as, for instance, when the power crusher is installed. According to para 278 of the Indian Sugar Committee's Report, the juice in the Rohelkhand **bel** system is boiled down to a massecuite of approximately 85° Brix, as compared with 95° Brix, obtained in a modern factory with vacuum evaporation. After repeated and careful examination of the samples of **rab,** produced by the improved methods, it has been reported by the analyst attached to the Department of Agriculture, Bhopal, that in the Bhopal samples the Brix figures have varied as follows :—

S39 or Yuba (a cane admittedly inferior in sucrose compared with other imported kinds)	89.70°
P. O. J. 33 (Lakhapur)	91.98°
S48	94.35°

The superiority of the **rab,** made by the improved methods from the better canes in comparison with the Rohelkhand massecuite needs hardly any comment, in the face of the above figures. **Having effected substantial reduction in the cost of cultivation and manufacture, and satisfied the local critics, by practical**

demonstrations, attention was directed to the suggestion made by the Indian Sugar Committee, in para 302 of their report, about the manufacture of muscovado sugar, or other intermediate product, suitable for working up into white sugar in large up-to-date factories in India. An endeavour to produce crushed powdery or mealy sugar, direct from the juice, proved highly successful, when the Manjav or S48, with their tops cut off for seed, were employed in the manufacture. This was a new form of sugar, hitherto unknown to the Indian sugar trade, and it fetched the high price of Rs. 15/- per local Maund (98.7 lbs). It has been given the name of **Kachcha Bura,** and is a great testimony to the superiority of the two said varieties over the Indian indigenous canes in general, and a recommendation in itself for the rapid extension of the cultivation of the varieties in the place of existing inferior canes. At this stage the centrifugal machine was used for the separation of molasses from crystals, but the product was a white sugar of varying degrees of brilliancy instead of a dark muscovado. The yield varied from 40 to 52 per cent, according to the variety of the cane used, and the care bestowed upon clarification and boiling. The Coimbatore seedling canes, and the S.48 and P. O. J. 33 (Lakhapur) gave a much higher return than the others, and the **rab,** boiled under the new system, gave a quality of **Khand,** incomparably superior to that produced in Shahjahanpur and Bareilly from **rab,** made under the old **bel** system, whether the sugar was separated by the centrifugal or the time honoured **Khanchi.** The first molasses eliminated by the centrifugal contained too much recoverable sugar to be sold to tobacconists who are the principal consumers. It was found that by re-boiling, the molasses could be converted into **gur** or **rab** of a lower grade, which, under the existing conditions of the local market, sold at Rs. 10/- per local Maund, as compared with Rs. 13/- or so for the first **gur.** If boiled to **rab** again, the second **rab** yielded from 36 to 40 per cent of its weight in the form of a pale brown sugar commanding Rs. 15/- per local Maund. The price varied a little according to the quality of the cane used, and, as usual, S48 stood highest in this treatment too. The second molasses would fetch the same price as the first if sold to the tobacconist, who is not concerned with the sucrose content of the material; also molasses was a very suitable raw material for the production and distillation of alcohol which, however, was prohibited in the State. It might, however, be used for producing alcoholic Motor spirit, if and when that industry is established.

The net result of the Bhopal trials has been an extraction of nearly 9 per cent of first and second sugars from the superior canes containing about 14½% of sucrose, and rather less from the inferior canes. This compares favourably with 4 per cent usually recovered by the Rohelkhand **Khandsari** by his primitive methods, and 5.6 per cent recovered by Mr. Hulme with his power plant

and centrifugal, both using the indigenous canes of Rohelkhand, from which the Indian Sugar Committee expected to recover about 9 per cent in an up-to-date sugar factory. These results, whether they may be due to the superior quality of the seedling canes and the high purity of their juice, or, in a greater measure, to improvements in the methods of boiling and machining the **rab** or to both causes, are so remarkable, that it has been deemed proper to publish them for general information. The Indian rustic cane grower, who spends his life toiling in the fields, does not worry himself about the efforts of the agricultural scientific workers of India, but it should be recognised that he owes a debt of gratitude to Mr. Clarke of the U. P. Department, whose researches, it is believed, brought S48 in prominence, and to Dr. Barber and his successor Mr. Venkatraman, who have patiently developed the various seedlings (far superior to the common indigenous varieties) which will, in time, bring about a revolution in the husbandry of the sugarcane in India. No less should the Indian sugar manufacturer be grateful to the said officers, whose labours have placed within his easy reach varieties yielding about 3 times as much raw sugar as he was accustomed to getting formerly, and of better quality, whether he works under the **Khanchi** system or by the centrifugal method.

Because the author has spoken in high terms of the work done by the help of the centrifugal machines, it must not be inferred that there are not many things to be studied about them. The operating speed must be known and maintained regularly, and experiments must be made until the copper mesh lining the cage is of the right size to drain out the molasses quickly, without an undue loss of sugar crystals, through the holes. Although the manufacturer can say that this or that mesh will be about right, he cannot say what is the exact size of the crystals of sugar going to be procured by a new process using a new cane grown in a new place. So many things affect the crystallisation that it is difficult to give the really final word upon such a matter without actual trial.

*The author has had the best service from the 18" under-driven "Handelox" machine and he is in communication with the makers, Messrs Thomas Broadbent & Sons, Huddersfield, about the machine. He hopes it will be possible to persuade the makers to introduce such improvements as will make the machine perfect either for hand power or steam power. To have such a machine capable of being handled successfully by the lowest labour is a matter of great importance.

So long as **gur** commands, as it does at present, a high price independent of the current prices of white sugar, Indian or foreign

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***Since the above was written Messrs Broadbent and Sons have brought out two types of 18" diameter centrifugal driven by hand and by power, both of which have given full satisfaction.**

viz Rs. 12/- to Rs. 13/- per local Maund (98.7 lbs.), it is obviously more profitable to manufacture **gur** in preference to white sugar. The probability is that within the near future the cultivation of the superior canes will extend with astonishing rapidity, for the Indian cultivator is too shrewd to let any improvement pass by, if he is convinced of its value, and the improvement is capable of easy adoption. It is only a matter of bringing these canes to his notice properly, by persuasion and demonstration, and the result will be a gradual but nevertheless rapid substitution of these new varieties for the old ones. With the extension of the cultivation both irrigated and dry (there being indication for a fairly successful future for the latter in certain parts of Malwa), a marked fall in the prices of **gur** will be inevitable, and it is then that the necessity for manufacturing some form of white sugar, directly from the cane, will become obvious in the tracts where operations are at present confined to the production of **gur.** It is for this reason that the figures relating to white sugar have been worked out at this stage so that they may be available for consideration and guidance when the time arrives. Meanwhile the manufacturers of **rab** and **Khand** in Rohelkhand will be welcome to draw their own conclusions from these figures and make such use of the general information published, as they think proper. The manufacturer of **gur,** in the Eastern districts of U. P., who sells the greater part of his produce to the refiners, ought to produce by the methods advocated, specimens of **gur** bound to command a price commensurate with their purity, colour and sucrose content, resulting in an appreciably high monetary return. Under the existing conditions of the local Industry the Bhopal State has to import over 33,000 local Maunds of **gur** annually to meet the requirements of its population, and even then the consumption corresponds to 5.88 seers per head per annum, or 1.2 tolas per head per diem, a rather low figure. In addition, the State imports over 34,700 local maunds of foreign and Indian white sugar consumed at the rate of 2 seers per head per annum. It is calculated that the existing area under cane cultivation in the State should be extended by about 736 acres, if the State is to be made self-supporting in the matter of its requirements of **gur** alone, and by another 868 acres if an attempt is made to produce white sugar sufficient to meet the existing local consumption. The scope for the increased cultivation of the crop in the State is thus too obvious to need comments.

In conclusion the author must acknowledge in most grateful terms the patronage extended to him in his researches by Her Highness the Nawab Sultan Jahan Begum, C.I., G.C.S.I., G.C.I.E., G.C.B.E., the enlightened Ruler of Bhopal (now retired), whose interest in the cause of Indian Agriculture and specially of Agricultural improvements in the State is proverbial, and who devoted personal attention to the progress of these experiments

and expressed a keen desire to publish their results. He must also acknowledge most sincerely the ready and generous help rendered, as Finance Member, by Her Highness' son, Lt. Col., Iftikharul Mulk, Nawabzada Mohammad Hamidullah Khan Bahadur, C.S.I., C.V.O. (now His Highness the Nawab of Bhopal), who provided the funds necessary for carrying out these experiments and equipped a chemical laboratory for determining the analyses. Without His Highness' munificence, the investigations could not have come to a successful conclusion so soon as they have. The author must apologise for the length of this brochure, but he had to enter into details even at the risk of repetition of statements and facts, as there are secrets in the art of sugar making at every stage, and he is anxious to prevent the enterprising layman, who may take to sugar-making, from finding himself at the mercy of the boiler and the centrifuger, whose carelessness, laziness, or lack of expert knowledge might lead to loss. A detailed statement of facts appeared therefore to be imperative.

The author's grateful acknowledgments are also due, to Dr. L. A. Jordan, D.Sc. etc. of London, Consulting Chemist to the Government of Bhopal, who, during his stay at Bhopal in 1925, perused most carefully the original draft of the book written till then, and offered suggestions which proved very valuable in subsequent compilation of the available matter, and to Mr. G. W. Douglas, B. Sc. etc., the Chemist in charge of the Bhopal State Laboratory, who was pleased to read through the record of experiments carried out during the two succeeding years. Very useful assistance was rendered by Pandit Darshanlal Dubey, Assistant Director of Agriculture, Bhopal and a diplomate of the Agricultural College, Saidapet, Madras, in collecting local information regarding cultivation of cane and manufacture by the indigenous methods, and about the present condition of the trade in the centrifugal-made sugar of Rohelkhand, while the chemical information contained in the book was enthusiastically elaborated by Mr. V. R. Mishra, L. Ag. (Cawnpore) in 1925 and by Mr. J. K. Dubey, M.Sc. etc. of Illionois U.S.A. in the years which followed.

Lastly, the author wishes to express his deep sense of gratitude to Sir Oswald V. Bosanquet K.C.S.I., President of the State Council, Bhopal, whose keen interest in the research and support towards its execution have gone a long way towards attainment and publication of the results in the form of this book.

Dated, Bhopal, S. M. Hadi, M.R.A.C. etc.

The 1st. October 1927.

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CHAPTER I.

Bhopal. Its Physical and Agricultural Aspects, Soil and Climate.

The State of Bhopal, comprising an area of 6902 square miles stands on the Eastern confines of Malwa in the Central India Agency, and next to Hyderabad it is the most important Mohamedan State in India. It lies between 22°–32′ and 24°–4′ N. and 76°–28′ and 78°–52′ E. being bounded on the North by the States of Gwalior, Basoda, Korwai, Maqsudangarh and Narsingarh, the Siraunj Pargana of Tonk State and the Saugor District of the Central Provinces, on the South by the river Narbada, on the East by the Saugor and Narsinghpur districts of the Central Provinces, and on the West by the Gwalior and Narsingarh States. The greater part of the State, 4017 square miles, is situated on the Malwa Plateau and is characterised by large meadows of pasture lands interspersed with rich fields of black cotton soil. The remainder, an area of 2885 square miles forms the hilly region. The plateau land is highly fertile and is capable of growing most of the Indian Kharif and winter crops including sugarcane.

The hilly region which is clothed in forest with patches of fertile soils at the foot of the hills, is part of the great Vindhya range. The average elevation of the main chain lying in the South of the State is from 1,800 to 2,000 feet, the highest peak having an altitude of 2,137 feet.

To the North two rivers of importance, the Betwa, which is one of the largest rivers in Central India, and the Parbati, each with numerous tributaries, flow towards the Jamuna Doab. The Parbati rises near the town of Ashta and flows for about 90 miles within the State and forming its Western boundary which it does throughout most of its course. The Narbada flows for about 125 miles along the Southern boundary of the State and is fed by many streams originating in the State.

The rivers and streams are however not used to any notable extent for irrigation of Agricultural crops, although irrigation is recognised as useful. Irrigation water is mostly taken from tanks and wells, particularly the latter. Water is drawn up from wells by the **Charas** (Leather-bag lift) or the Dhenkli, a counterpoised beam method of lifting water. The long beam is carried on an upright post with a vessel attached at one end and a weight at the other. From tanks irrigation water is taken by means of channels and gravitation or it is first lifted as in the case of wells.

Orhis (reservoirs) fed from streams are occasionally constructed to serve the purpose of a temporary well for irrigation purposes. Sometimes a Persian Wheel, generally made of wood but occasionaly made of iron, is used for lifting water.

Only about 26 per cent of the total area of the State is under cultivation, viz: 1800 square miles out of 6902, and of this cultivated area only 35 square miles or a little less than 2 per cent is reported as irrigated. The total population of the State according to the census of 1921 was 692, 448 giving a mean density of population of 100 per square mile, of whom 60 are engaged in agricultural and pastoral persuits. Of these 60 persons, 49 are workers actually engaged in agriculture. On the basis of the above figures each cultivator is responsible for an average holding of 3.38 acres which is too big an area to be managed properly by a single worker, and to some extent, this accounts for the backwardness of agriculture in the State generally. The need for increased population especially among the labouring classes is a very pressing one, if there is to be steady improvement in agriculture, for at present labour is difficult to get and unduly expensive in Bhopal. Indeed there is such scarcity of labour that cautious Mustajirs (farmers), who derive their livelihood mainly from agriculture, as a rule, make heavy advances of money to professional labourers as the only means of binding them to continuous service. Sometimes they lose money in such transactions, but in this way the timely conduct of field operations is assured. Even Government Farms in which wages are paid at reasonable rates and with due punctuality have to resort to this plan to ensure their command over manual field labour.

Cane is grown with irrigation mostly in villages situated on the banks of natural streams in which the water remains throughout the year, as, for example, the villages of Kothari and Maina in the Ashta District in which the largest compact blocks of cane are seen every year. Here the main source of irrigation is a **nala,** the water being lifted by means of the **charas** worked on **Orhis,** (reservoirs fed from the streams). There are as many as 28 of these watering stations in the above villages, but the practice of watering is confined to certain localities where cane cultivation has been carried on from time immemorial and is not adopted generally all along the banks of the stream. Similarly the larger streams, such as the Satdhara, Halali and Patra are not freely made use of for irrigation purposes, though on the banks of these streams sugarcane could be cultivated with marked success.

Also the introduction of Agricultural Machinery which can be managed by the village blacksmith of average mechanical intelligence, supervised by more skilled artisans, is highly desirable. The cattle are strong enough to work fairly heavy iron

ploughs, such as the American "C. T." or the Cawnpore "Watt's" which may be adopted for inverting soils and ploughing them deep. But a very remarkable improvement seems likely with the introduction of Portable Power Driven Pumping Plants for lifting water for irrigation purposes from streams which at present are not used. There is little doubt that by the use of a suitable type of pumping apparatus a great improvement could soon be effected in the cultivation of sugarcane, wheat and other remunerative crops. It is in this matter of making use of the available water that a beginning may be most advantageously made towards the introduction into India of modern agricultural machinery of not a very expensive character. Power lifts suitable for irrigation from deep wells are far too costly to be adopted by the Mustajir (farmer) and too complicated to be entrusted to the local mechanic. The statistical information contained in the foregoing paragraphs has been culled from the Bhopal Gazetteer published in 1908 and the Census Report of Central India issued in 1923.

The following table shows the meteorological conditions of Bhopal.

Rainfall at Bhopal

1922	(January to-December)	34.86 inches.
1923	do	55.39 „
1924	do	37.72 „
1925	do	36.45 „
1926	do	50.48 „
	Average	42.98 „

Temperature.

	Maximum		Minimum	
1922	30/5	102° F	4/1	52° F
1923	1/5	104° F	1/1	56° F
1924	10/5	106° F	7/1	54° F
1925	17/5	105° F	9/1	54° F
1926	12/6	104° F	29/12	54° F

CHAPTER II.

Composition of Soils.

A. For Revenue Settlement purposes soils have been classed locally by their appearance, situation and conformation and crop-bearing properties. According to the first classification the soils are known as :—

(1) **Kalmat** or **Moran:** a fertile loamy soil, varying from 1 to 10 feet in depth, of black colour interspersed with small white nodules. When dry it becomes very hard and cracks but when wet it is soft and clayey. Owing to its power of absorbing and retaining moisture, it remains soft for a considerable period. It is suited specially to Wheat, Sugarcane, Masur (Ervum Lens) and gram. An inferior form of this class of soil, lighter in colour and texture, being mixed with a certain proportion of sand is called **Kalmat Dom** or **Kalmat** II. **Kalmat** is not so good for Kharif (rain) crops as the others which follow.

(2) **Bhanwar:** a grey coloured soil of loose texture believed to be a mixture of **Kalmat** and **Siyar** (see below). Its clods are soft and yield readily to the plough. The soil is highly retentive of moisture and yields a fair crop even if the winter rains (Mahawat) fail. It is suited to Wheat, Cotton, Linseed and Juar (Sorghum Vulgare). It would grow sugarcane where irrigation is available. When lying fallow it produces a fine grass known locally as **Kil Machael.** There is an inferior class of this soil much less retentive of moisture.

(3) **Siyar.** Under this name are classed the poorer soils of a grey or reddish black colour, and a loose and sandy texture. This soil does not crack when dry and with irrigation is suited to rice cultivation and produces fair crops of other Kharif staples. Being shallow and not retentive of moisture, the crops grown on it are liable to dry up if the rainfall is not ample. In a low lying position it is capable of growing Wheat and Gram. Other soil conditions recognised by the agriculturists are :—

(i) **Domat** or **Dumat:** a mixture of **Kalmat** and **Bhanwar.** It does not crack like the black soils, being somewhat sandy and of a brown colour.

(ii) **Piluta :** practically a form of **Siyar** having a yellow or brown colour, never very deep, full of small pebbles and found on the slopes of hills and suited only to Kharif crops.

(iii) **Bhatwa:** a light sandy shallow soil of red or brown colour found mostly on the slopes, or at the foot of hills, seldom more than one foot deep. It grows only the less valuable crops **Kodon** (Paspalum Scrobiculatum), **til** (Sesamum Indicum) and Maize (Zea Mays) and is liable to become exhausted after two years of continuous cultivation. The word **Bhatwa** signifies 'stony.'

(iv) **Kachhar** or **Chhap :** an excellent loamy soil found on the banks and in the beds of streams. It grows fine crops of Wheat, Juar (Sorghum Vulgare) and vegetables. The soil of the two Government Farms of the Bhopal State viz Nabi Bagh and Nuzhat Afza, 2 and 4 miles respectively from the city, is **Kalmat** or **Moran.** It is said that Bhanwar is better suited for sugarcane, but the experiments that are referred to in this book were confined to **Kalmat** land.

B. Half a dozen typical samples of **Kalmat** obtained from the Government Farm at Nabi Bagh in accordance with instructions for taking samples received from Dr. Harrison, Imperial Agri ultural Chemist, were analysed by the said Officer in the beginning of 1920.

Of surface soil several samples were taken from each typical area to a depth of 8 inches. All these samples were mixed well together, spread out and allowed to dry in the shade. The samples for analyses were then taken out of the mixture and despatched. The same procedure was adopted for preparing samples of the subsoil, earth being taken from the 8th to the 16th inch below the surface

A copy of the report furnished by Dr. Harrison is given below :—

Laboratory No.	151/19	152/19	153/19	154/19	155/19	156/19
	Surface soil block I %	Sub-soil block I %	Surface soil block ii culti-vated with **bakhhar** %	Sub-soil block ii culti-vated with **bakhhar** %	Surface soil block ii **Kans** infest-ed patch %	Sub-soil block ii **kans** infested patch %
Loss on ignition	3.95	4.197	4.018	4.101	4.943	3.39
P_2O_5 (total)	0.060	0.064	0.081	0.065	0.084	0.075
P_2O_5 (available)	0.0033	0.0033	0.0051	0.0064	0.0045	0.002
K_2O (total)	0.576	0.619	0.633	0.622	0.683	0.563
K_2O (available)	0.015	0.013	0.0185	0.0123	0.016	0.011
CaO	2.116	2.000	2.675	2.366	1.745	2.247
MgO	0.990	0.988	1.052	1.338	0.912	0.968
CO_2	0.733	0.585	0.804	0.857	0.397	0.515
Organic nitrogen	0.033	0.027	0.043	0.036	0.042	0.035
Size of particles			Mechanical analyses.			
.000–.002 mm.	0.69	1.22	1.02	1.02	0.77	0.71
.002–.004 mm.	4.00	3.44	4.01	3.62	3.90	4.00
.004–.008 mm.	3.77	4.02	4.90	4.19	4.36	4.26
.008–.016 mm.	5.75	5.71	7.10	5.84	5.77	6.21
.016–.032 mm.	21.52	18.79	21.31	19.01	18.59	18.52
Sand	64.27	66.82	61.66	66.32	66.61	66.30

"The soils are very similar in character and are characterised by the high proportion of coarse grade sandy particles composing them. Regarding their chemical composition, they are well supplied with lime and total and available potash, but are very deficient in nitrogen and available phosphoric acid.

It is probable that manuring with green manures in combination with superphosphate or basic superphosphate will answer very well and at the same time the use of organic manures will tend to correct the faults in the physical properties of the soil due to coarse structure."

Other soils have not yet been analysed chemically.

CHAPTER III.

Production of Sugar in the Bhopal State,

Exports, Imports & Consumption.

The area annually under sugarcane in the state is according to the average of the past five years about 4,533 local **bighas** or 3,173 acres of which about 287 acres are cultivated dry. As the whole of the crop is usually converted into **gur,** this area may be assumed to yield 71,920 local maunds of **gur** per annum, taking one ton (27.2 standard or 22.66 local maunds) to be the average yield per acre. The imports of **gur** amount on the average to 33,133 local maunds annually. The total of import and manufacture is 1,05,053 local maunds of which quantity an average of 3,145 local maunds is annually exported, leaving a balance of 1,01,908 local maunds available for consumption. With a population of 6,92,448, which is the population of the State according to the last census, the consumption corresponds to 5.88 local seers per head per annum or 1.2 tolas per head per diem, showing that the population is unable to get enough raw sugar to meet the ordinary human requirements.

Assuming that superior canes are introduced and cultivation is extended by a system of state encouragements, then to make the state self-supporting in the manufacture of **gur,** at the present consumption, would require, at 45 maunds of **gur** per acre, an area of $\frac{105053}{45} = 2{,}335$ acres. If the existing varieties of cane yielding only 1 ton per acre of **gur** are adhered to, then an area of 4,670 acres is required instead of 3,173 acres at present under cultivation.

In addition, the average import of white sugar, foreign and Indian, into the state amounts to 34,729 maunds per annum, which may be taken to be all consumed, equivalent to 2 seers per annum, per head of the population. At 40 maunds of white sugar per acre the area required of superior canes to satisfy the white sugar demand would be

$$\frac{34{,}729}{40} \quad 868 \text{ acres}$$

Thus with superior canes we should have,

for **gur**–2,335 acres

for sugar-868 acres

Total 3,203 acres.

to cover the internal consumption of the state which is but little more than the area under sugarcane at the moment. As however it must take time to supplant the poor indigenous cane entirely, there is scope for extending the present area by 1,600 acres or so to produce raw sugars which could readily be consumed in the state itself. The desirability of increasing the cultivation of cane deserves as much attention from the peasantry and the farmers as from the state authorities, if not more so. The cultivation having been simplified, the cost materially reduced, and the seed of the superior varieties being available at the State Farms, the matter is receiving earnest consideration from all concerned.

CHAPTER IV.

The indigenous and imported varieties of sugarcane grown in the State. The seedling canes, their origin and character.

A. CANES GROWN WITH IRRIGATION.

Four varieties viz (1) **Munhtora,** (2) **Mankia** or **Mandkia,** (3) **Bhelsai** or **Bhelsani** and (4) **Khajla** are usually grown with irrigation. **Bhelsai** was introduced only about a quarter of a century ago, presumably from the neighbourhood of the Bhelsa town (Gwalior State), hence the name, the remaining three being the local kinds grown from time immemorial. **Bhelsai** which perhaps belongs to Dr. Barber's Pansahi group gives the largest yield of **gur** and requires less irrigation than the others and is therefore gaining popularity. **Mandkia** is perhaps a cane of Dr. Barber's **Nargori** group and is similar to the **Kewahi** of Jaunpur (U.P.). **Munhtora** appears to be a member of the **Mango** group of the Benares and Behar canes. With regard to the quality of **gur** yielded by these canes **Khajla** occupies the first place followed in the order of merit by **Munhtora, Bhelsai** and **Mandkia,** but with reference to the quantity of the yield **Bhelsai** ranks first, **Mandkia** stands second, **Khajla** third and **Munhtora** last. **Mandkia** fails generally in a year of excessive rainfall and ordinarily the **gur** it yields is wanting in the right flavour, owing to a high percentage of salts in the juice and is therefore being rapidly replaced by the **Bhelsai** variety.

Khajla though acknowledged generally to be the best variety on the whole, is practically confined to the villages of Maina and Kham Khera in the Ashta Tahsil. It is alleged that it does not flourish in other cane growing centers for reasons not altogether clear. The cane is becoming scarce even in the two above named villages, being liable to heavy damage by wild animals. Owing to the softness of the cane and its juicy character it is relished more than the other harder varieties.

Khajla canes have streaks all over the stem and resembles **Nasik Khadia** in general appearance. Nasik Khadia is an imported Indian variety grown experimentally at the Nabi Bagh Farm in Bhopal. It is an erect cane of the type of the Dhaur of the U. P. having lanceolate leaves and is pale in colour when at maturity. It yields a very light pale coloured **gur** which is highly prized in the market. The sugar obtained by the centrifugal from the **rab** of Nasik Khadia has generally a slight tinge of pale yellow, unlike that of Bhelsai which is generally white. Its cultivation is hitherto confined to Government Farms, although it is one of the best canes suitable for production of superior **gur.**

The following table gives the distinctive characters of three of the

	Munhtora
(a) **The stem**	
(1) Height	2 to 4 feet
(2) Colour	Greenish pale
(3) Cross section	Fairly round
(4) Bloom or Ashy Coating	Thin, white, uniformly distributed.
(5) Thickness	$1\frac{1}{2}''$ to $2\frac{1}{2}''$ in circumference
(6) Solidity	Fairly hard
(7) Weight	Heavier than the Bhelsai canes and lighter than Mandkia
(8) Rind	More adhesive to the interior part than the rind of **Mandkia** and less so than of Bhelsai
(9) Grooves on the internodes	Slightly marked extending from the point of bud to the middle of the internode
(10) Nodes	Almost on a level with the internodes
(11) Internodes	$1\frac{1}{2}''$ to $3''$ in length
(12) Buds	Small and sunk in the basal joints and with a tendency to shooting in the young joints
(13) Growth ring	Not so marked as in **Mandkia** and Bhelsai canes
(b) **The leaves.**	
(1) Blades	Narrow erect but bending at tips only
(2) Leaf sheath	Sheathy extending to the 5th joint above
(c) **The leafy tops** (called "Band")	Largest of the 3 varieties comparing the size of the canes
(d) **The aerial roots**	Fibrous extending to three or four joints above the ground

common varieties, and it may be referred to for purposes of identification:—

Mandkia	Bhelsai
4 to 8 feet	4 to 8 feet
Greenish pale	Greenish pale
Slightly flattened	Slightly flattened
Dark localised forming patches	Black localised forming patches, denser than on Mandkia canes.
$1\frac{1}{2}''$ to $3''$ in circumference	$2''$ to $4''$ in circumference
Very hard	Softer than the canes of the Mandkia and Munhtora varieties.
Heaviest of all	Lightest of all
Easily separable from the interior part but thick and strong	Adheres very fast to the interior part.
Well marked extending nearly to 3/4 of the internode	Not perceptible
Bulged out prominently	Bulged out more prominently than those of Mandkia
$3''$ to $9''$ in length	$2''$ to $5''$ in length.
Small but well developed all over the cane	Well developed all over the cane with a rounded base and a long tapering apex.
Well marked	Well marked
Broad spreading out from the cane and then drooping down from about the middle	Broad and erect but bending at tips only
Sheathy extending to $2\frac{1}{2}$ to $3\frac{1}{2}$ joints above	Sheathy extending to $2\frac{1}{2}$ to 3 joints above.
Shortest of all in length	Shorter than those of Munhtora and longer than those of Mandkia.
Fibrous	**Extending to 3 or 4 joints above the ground.**

B. Canes grown without irrigation.

The general belief, which by experiment has been found to be groundless, is that only a limited number of specific varieties can be grown without irrigation. The fact is that nearly all thin and medium canes can be grown without watering though not all with maximum success. It is only the thick canes of the soft Paunda class that wither away in summer if grown dry. For example P.O.J. 33 (Lakhapur) has failed to grow under dry conditions. Three varieties are cultivated dry in the Tahsil of Raisen viz **Kansia, Ledu** or Ledara and **Dhaul.** The last two yield good grainy **gur,** but that obtained from **Kansia** is usually very poor in quality. Another variety is cultivated in the Pargana of Sultanpur, viz **Barru, Bharra** or **Sarari.**

The following is a description of the above varieties.

Kansia.

The name Kansia is derived from **Kans** or **Kansa** (Saccharum Spontaneum), the notoriously obstinate weed which the cultivator finds very difficult to eradicate. **Kansia,** which seems to be a primitive local variety of sugarcane, may be only a form of the **kans** grass developed by the natural process of evolution.

(1) **Roots.** Adventitious, strong and profuse growing from 3 to 15 joints from the ground upwards.

(2) **Stem.** Tall and slender with a central cavity containing pithy filaments.

- (a) **Length.** 5 to 8 feet.
- (b) **Girth.** $1\frac{1}{2}$ to $2\frac{1}{2}$ inches.
- (c) **Colour.** Light green with brown patches especially on the lower part, spots of dark bloom, which, when the cane is nearing maturity, develop into black marks intermixed with brown ones. There is also a white bloom all over, which is well defined and uniform. At maturity the canes become red.
- (d) **Rind.** Hard adhering firmly to the inner part.
- (e) **Internodes.** 1" to 3" near the roots and 3" to $6\frac{1}{2}$" in the middle and upper parts of the cane.
- (f) **Nodes.** Prominent with the growth ring well defined.
- (g) **Buds.** Small and sunk. Canes are fairly round with a shallow groove running from the point of bud to the upper joint.

(3) **Leaves.** Alternate with long sheathy petioles and lanceolate blades. The petioles cover the entire stem at the joints and overlap each other throughout their length, which extends to the upper two joints, and thus they form a complete sheath round the stem. The blades are fairly erect in growth with a prominent broad, thick and white mid-rib.

Ledu or Ledara.

The word **Ledara** means flabby or fat. The canes of this variety are generally thicker than those of the Kansia with internodes slightly buldging in the middle; hence the name.

The Ledu is almost similar to the Kansia, differing only as under :—

Stem. Hard with a pithy centre in the upper part, canes slightly thicker having only a faint white bloom all over.

Leaves. The midrib neither so broad, nor so thick or white.

Buds. Prominent.

Dhaul.

The word is derived from the Sanskrit word **Dhawal** which means white. The canes of this variety are pale when mature.

Roots. Similar to those of Kansia.

Stems. More rounded than those of Kansia and Ledu with the grooves only faintly perceptible. Length, 4 to 6 feet; thickness, $1\frac{1}{4}''$ to $2\frac{1}{4}''$. Colour, pale white with patches of the black and white bloom and with brown streaks here and there.

(a) **Rind.** Soft and more easily separable from the inner parts as compared with Kansia or Ledu.

(b) **Internodes.** $1\frac{1}{2}''$ to $2\frac{1}{2}''$ in length near the roots and $3''$ to $4''$ in the upper part.

(c) **Nodes.** Similar to Kansia.

(d) **Buds.** Similar to Kansia.

Leaves. Slightly broader than those of **Kansia** or **Ledu.** The petioles are also comparatively long extending up to the 3rd or 4th joint above the base. The midrib is not so prominently white and has a greenish border line on either side. This cane is identical with the Agaul of Rohelkhand, Gagaul of Meerut and the Katara of South Oudh.

Barru, Bharru or Sarari.

The name Barru or Bharru seems to be derived from the word **Bharuhi** which means "reed", to the characteristics of which it resembles in growth, being thin, long and erect. Sarari signifies "thin and tall."

The colour of the stem is pale yellow with a white bloom.

Internodes. $1\frac{1}{2}''$ to $3\frac{1}{2}''$ at the bottom and $5''$ to $6''$ up above.

Nodes. On a level with the internodes with the growth ring very faintly marked.

Buds. Very small and flat.

Leaves. The lamina and midribs are similar to those of the Dhaul, but the petioles are not so long, extending only to the second joint above the base.

C. Seedling Canes.

The term "seedling cane" is not generally understood by the layman, and it is therefore desirable to explain the term in some detail. Speaking briefly it means cane raised by seed. Propagation by seed is only possible when the parent cane flowers and the flowers form seed. As a matter of fact, however, most of the thin canes do not flower at all in Northern and Central India. Some of the red canes, however, do flower in their homes in Northern India, e.g. the Chin or Ramui and the Saretha. The Dhaul of Central India also flowers sometimes in Malwa; but these flowering varieties do not appear to bear seed. The thick white Paunda does not ordinarily flower in either of the two sub-tropical tracts.

A very strong superstition exists among illiterate cultivators of all communities in Upper and Central India alike, with regard to the flowering of canes–a feature looked upon with great disfavour and considerable concern, being regarded as an indication of divine displeasure. Indeed the feeling against it is so intense that a cultivator would willingly burn or otherwise do away with a flowered crop, if he could afford to do so. But he does not do so as financial considerations compel him to utilise the crop somehow, in an unhappy state of mind. As this book is intended mainly for enlightenment of cultivating classes of Malwa and the neighbouring sugar growing tracts for whose benefit a translation of it in the vernacular will probably be published, the author is taking the liberty of writing at some length about the advantage of the flowering of cane and the important part it plays in the cultural

improvements of the crop. He hopes that his remarks may lead to some alteration in the hostile belief which is prevailing now. The superstition does not seem, however, to be entirely without foundation. It has been remarked by some of the writers on sugar that flowering is an undesirable feature of cane growth. According to Mr. Vankata Rao Badami of the Mysore Agricultural Department, "if the cane flowers, the tonnage per acre is greatly reduced. Therefore the flowering habit is a great defect in any cane for our conditions here." In dealing with the history of work on sugarcane the Indian Sugar Committee has observed (Vide page 204 of their report) that "the tendency of some varieties to flower freely militates against their introduction, as this is found to reduce the yield of sucrose in the cane." Rao Saheb T. S. Venkatraman, Government Sugarcane Expert, has however, expressed the opinion (Pusa bulletin No 94 of 1920) that "arrowing in canes has no immediate harmful effect on the sucrose content, but leads to the stoppage of all further vegetative growth and the formation of pith in the centre, if the crop is kept in the ground long after the arrowing."

These remarks have been found to be in agreement with the observations made in Bhopal, where the imported seedling canes and the local Dhaul flowered profusely during the past three seasons. Here the flowering begins in the latter part of October and continues till January. Analyses were regularly made of the juices of flowered and unflowered canes and it was found by the chemist that "the flowered (mature) cane invariably gave a higher sucrose content than the unflowered (immature) ones." This was the case until the last week of February, but later the loss both in tonnage and the sucrose was distinctly perceptible. The fact therefore seems to be that the Malwa cultivator who generally works with only one crushing mill and two pairs of bullocks and has also to plant and irrigate his next crop during the winter, cannot find the means of converting his flowered standing crop into **gur** quickly and is compelled to face the inevitable loss which may be heavy proportionate to the delay in crushing and boiling—a serious disadvantage. This is presumably the reason for the superstition. It may here be mentioned casually how important it will be in view of obtaining a full outturn, to introduce a power crusher for dealing quickly with flowered crop of seedling canes which usually flower freely and are grown extensively in Malwa.

To understand propagation of seedling canes the layman should know that the cane flower contains both male and female organs within itself. The male organs (anthers) produce the fertilising agent technically called "pollen.". The female organs consist of the parts known to scientists as ovary, stigma and style.

It is the ovary that produces the seed after being fertilised by the pollen by the action of wind or otherwise. Flowering takes place at definite times of the year (November and December in Bhopal). According to Noel Deerr "if the cane is not sufficiently mature at the flowering time in its first year, no formation of flowers occurs until the second year. In this way a delay of a few weeks in planting will retard flowering for 12 months." According to the same authority the general belief in the world about 40 years ago was that cane was infertile, as is the common belief to-day among the cultivators in India, although the fruit of the cane had been described by Dutrone in 1790 and Parrs had stated in 1859 in Barbados that he had observed cane seedlings, and the statement was confirmed by Drumm 10 years later. About this time seedlings were tried on a field scale in Barbados but owing to development of unfavourable characteristics their cultivation was given up. In 1888 Soltwedel discovered in Java that there were not only fruits in the cane flowers but that they could be successfully employed for the production of seedlings. In the succeeding year Harrison and Bovell discovered this independently and demonstrated the same fact in Barbados. Since then many valuable varieties have been evolved as a result of efforts made by eminent workers such as Went, Kobus and others in Java, Boname and Perromat in Mauritius, Eckrat in Hawaii, and Harrison Jenman and Bovell in the British West Indies. Private enterprise in Demarara, Australia and Brazil is also credited with the propagation of a number of new seedlings.

"It was observed at an early stage" says Mr. Noel Deerr "that the Cheribon cane in Java had no fertile pollen, whilst the ovaries of the flower were normal; hence the plan of growing in alternate rows a pollen bearing variety and the Cheribon cane arose. Most of the Javanese seedlings have been thus obtained." It is this process that is known as "crossing" or "propagation by cross-fertilisation." When a seedling is raised from a seed produced by a flower which has not been cross-pollinated, i.e. fertilised by the pollen of the flower of another plant and when due precaution has been taken to keep out other pollen it is called "selfed." Kobus the distinguished pioneer in Java stated to have principally used the Chunni (the Chin or Ramui of the U.P.) as male parent for fertilising the mother cane of Java. Elsewhere the seedlings raised are said to have been adventitious, the male parent being uncertain. "In 1904 Lewton-Brain in Barbados and Mitchell in Queensland emasculated cane flowers and fertilised them with pollen from another variety thus obtaining hybrids of certain parentage, but the skill required and the small number of hybrids obtained........make it doubtful if the method is advisable." (Noel Deerr).

Another technical term often met with in the current literature on sugarcane and not understood by the layman is the word "Sport." In biological vocabulary the term means an animal or plant, or one of its organs that varies singularly and spontaneously from the normal type. When applied to cane it signifies a plant which in some way is notably different from its parent. It has been observed in Bhopal that a striped Mauritius cane throws off a green sport with no stripes at all on the internodes, or with stripes only on one or two of them, and the Lakhapur Red (a thick acclimatised cane) produces a dark red sport differing not only in colour but in sugar content. Similarly instances have been noticed in other parts of the world in which a plant while producing striped canes from one eye produced green canes from another eye both of which eyes belonged to the same piece of cane, while another plant produced both striped and green canes from one and the same eye.

One of the foreign observers, Mr. M. Hall, writes as follows:—

" I have in one instance seen no less than three distinct canes springing from one stool of the Ribbon variety, one entirely yellow, one entirely green, the other being the usual Ribbon cane; while from the other stools in the same field I found canes either of a uniform green, purple or purplish brown; all the rest spring from the same Ribbon cane root being striped in the usual way." It is believed that the sports originate from bud variation-a natural process. On the basis of evidence collected by Mr. Noel Deerr, he has expressed the opinion that "it is established beyond reasonable doubt that certain of the more valuable cultivated varieties have so originated."

The Chamli and the Dhumar of the Western districts of the U. P. which are believed popularly to be degenerated forms of the Dhaur, might be "sports" sprung up as a result of natural bud variation.

In Java the outturn of raw sugar per acre was 1.6 tons in 1860. In 1880 it rose to a little over 2 tons as a result of better cultivation of the existing varieties. In 1887 work was started on the breeding of the sugarcanes. With the seedling canes under modern methods of scientific cultivation employed by European growers and factory owners, the outturn rose to 3.75 tons in 1900 and reached 4.5 tons in 1918. But in Java, like India, the cane grown by the indigenous population under the old system still yields only about 1 to a little over 1 and 1/3 tons of raw sugar per acre. The difference in favour of seedling canes and improved cultural methods is so marked as to hardly need any comment. The heavy import of cheap foreign beet and

cane sugars into India during the 12 or 13 years preceding 1911 and the consequent losses sustained by the Indian sugar producer in the competition, made the Government of India in 1911 take into serious consideration the different economic problems with which the indigenous industry was then confronted, and on the recommendation of the Board of Agriculture, which proposed the establishment in Madras of an acclimatisation and cane breeding station, they obtained with the concurrence of the Madras Government, the sanction of the Secretary of State, in the following year, to the opening of such a station at Coimbatore and the appointment to its control of Dr. Barber, then Economic Botanist to the Government of Madras, for a period of five years which was afterwards further extended. For the expenses of the new Research Station during the first five years the Government of India made the liberal allotment of Rs. 2½ lakhs from the Imperial Revenues.

The main object of the institution was to evolve through breeding, seedlings superior to the canes under cultivation, in order to secure substantial improvement in the acreage outtrun in various parts of India, especially Northern India, which commands the largest area, but in which the varieties commonly grown are thin and the yield is poor compared with Madras and Bombay, where the canes cultivated are thick canes of the Paunda class which give comparatively high outturns though much less than in foreign countries. The programme of the work laid down for the new station required careful scientific study of the three main sources of the world's improved varieties, viz., (1) bud variations or "sports" consisting of mutations rising spontaneously in the fields (2) selection including the acclimatisation of exotic varieties and (3) the cross breeding of seedlings. The ultimate result aimed at was to produce canes which would replace inferior varieties all over India, by giving a higher sucrose yield per acre when grown by improved methods under suitable conditions of soil and climate. Coimbatore was chosen in preference to a Northern India station because the canes in that neighbourhood flowered naturally and many of them produced fertile seed, a fact which rendered both propagation by seed and cross breeding practicable, contrary to the conditions prevailing in Northern India where ordinarily canes do not flower and can not for climatic reasons be induced to flower. A great many varieties from different parts of India were collected at the station and acclimatised, with the ulterior object of making them flower, and efforts made towards evolution of seedlings suited to the varying condition of soil and climate in India "with a high percentage of sucrose in the juice, great vigour and good habit." In sugar phraseology "vigour" signifies weight of harvest, "habit" denotes "whether the canes in the clump stand upright or are slanting, or

fall about in all directions seriously interfering with subsequent cultural operations." The straightness of cane is a character of considerable importance with reference to the sugar content, facility of transport and that of packing on the hoppers at the mill. The "lodged" or laid canes have usually a poor sucrose content. Attempts were made at Coimbatore to produce seedlings, both by direct sowing of seed and by crossing one variety by another. It was found that unlike other crops, when sugarcane seedlings were raised from the same parent, the resultant plants did not resemble one another or the parent itself in characters. This peculiar phenomenon gives rise to the production of new varieties which, when once selected, are afterwards multiplied by means of sets or cuttings. From this wide range of seedlings raised from any variety at Coimbatore, such of those as are prominently superior to the parent in chemical, botanical and agricultural characters, are selected for further testing and multiplication through cuttings. The rest are rejected. Very often from a batch of over a lac of seedlings hardly two are selected at the end of the repeated tests.

The inflorescence of the cane, which is "a panicle of soft silky spikelets, borne on the end of an elongated peduncle arising from the terminal vegetative point of the cane" is technically called "the arrow." For cultural purposes arrows are collected at a stage when the individual flowers constituting the inflorescence are dropping off on their own account, that is to say, when the seeds formed are quite ripe. Such arrows are crushed gently between the two hands and the fruits of the cane flower, along with their appendages, are separated in the form of fluff (a cotton like substance). This fluff is laid in a thin even layer on earthen seed pans, filled previously with a mixture of equal parts of horse dung and sand; no soil being laid on the fluff. The first watering is done by a spraying apparatus (the **Hazara**) held about 5 feet above the pan, the impact of the falling water gathers round the seed a certain amount of soil, which is all that is needed for germination. After sowing, the pans are kept in the open and moisture maintained by watering them 3 to 4 times during the day. At this stage, the seedlings which are delicate need constant watching, and laying of the soil round the germinated seeds is necessary in order to obtain satisfactory results. When about three weeks old, the seedlings are transplanted in other pans or pots filled with manured garden soil. When three months old, the plants are ready to go into the field. For field planting, the leaves require to be cut with scissors, a delicate operation requiring skilled performance, the object being to avoid destruction of the roots in transplanting. Seedlings thus prepared are planted in pits 2 feet $\times$ 2 feet $\times$ 2 feet or in trenches very carefully prepared and with very fine tilth, at distances of 4 to 5 feet between the rows and 2 to 3 ft. between plants in each row. Each plant

is now treated as a new and separate variety and studied in all its agricultural and botanical characters. Chemical analyses of the juices are made at the time of maturity. The best of them are selected and planting done from their cuttings for further tests.

Turning now to the process of cross-breeding, it should be remembered that it often happens that either the anthers or the pistils in the cane flower are infertile (Hindi, **banj**, Arabic, **aqar**). For crossing purposes, varieties in which the anthers are infertile, are used as mothers. Anthers (Persian, **zar-i-gul**) are infertile when they do not contain healthy pollen (Sanskrit, **Makrand**) and in such cases they do not open.

Between 5 A. M. and 8 A. M. the stigmas are generally most receptive to pollen. At this time the pollen of the variety to be employed as the father, is sprayed or dusted on the stigmas. It is very difficult to cross-pollinate a flower which has a pollen of its own, because the flowers are very minute and do not stand handling. It has been found at Coimbatore that even a violent human breathing permanently injures certain arrows i.e. kills the vitality of the flower. Because of this feature emasculation of the male, which is possible in cotton and wheat is impossible in the cane. The cross-pollinated arrows are covered with a cloth-bag to prevent pollination from other undesirable sources and the process is called "bagging." Arrows pollinated but not so protected are called "unbagged." If the stigmas are dusted with a certain desired pollen at the right time and fertilisation effected, the flowers will always refuse any other pollen borne to them by the wind. Therefore when the stigmas are properly pollinated, no "bagging" is necessary, but proper pollination can only be done by experienced hands.

The tropical types of thick or Paunda canes generally give rise to seedlings of the same types without cross-pollination. It is unfortunate however that the canes of the Northern India types even when they do flower, give seedlings inferior to themselves unlike the **paunda** canes, and this is a great draw-back. Crossing between the paunda canes and the poor but hardy and deep rooting Indian canes has therefore been found necessary for producing superior strains likely to suit sub-tropical India.

The **Kans** grass (saccharum spontaneum) has been found of use in breeding vigorous, hardy and deep-rooting seedlings. It is only with this one grass belonging to the genus saccharum, that successful results have been obtained in the matter of breeding. Crossing with this grass introduces in a cane population, hardiness, resistance to disease, and a deep-rooted system, but unfortunately the purity of the juice in the resultant seedlings is lower. "Purity" means a high concentration of sucrose, and comparatively low quantities of other constituents harmful for sugar manufacture.

For raising seedling cane the seeds whether cross-pollinated or not are never separated, the fluff itself being used for sowing.

The arrows found in Bhopal crops were examined by Mr. Venkatraman and found to be infertile in the male elements. The anthers had not opened and were twisted. The pistils could not be examined but he expressed the opinion that they were likely to be infertile because of the climatic conditions.

Reference has been made in the foregoing remarks to making the canes flower, or inducing them to do so. The red varieties of Upper India which flower in their homes only occasionally or sparingly, do so freely in Coimbatore conditions. The members of the Kewahi and Mango groups of the U. P. however, refuse to do so even under those conditions. Seedlings show a tendency to flower specially when they are the outcome of crosses between a thick cane and the **kans** grass (Saccharum Spontaneum). Unfavourable conditions of growth e.g. bad cultivation, water-logging and incidence of disease induce flowering to a certain extent. In fact interference with the vegetative growth of plants results in stimulating reproductive activity i.e. production of flowers. As water-logging often induces flowering in the cane, flooding is resorted to as a means of inducing reproduction.

It was by following the methods described above that a large number of new seedlings with high purity of juice and richness in sugar were evolved at Coimbatore and distributed to various Farms in India where their merits were tested. Coimbatore is still carrying on the breeding work and might develop still richer varieties.

Indian seedling canes tried at Bhopal.

The Coimbatore seedlings imported from United Provinces' Farms and tested on a field scale in Bhopal were, (a) Co 221 which is a cross between P. O. J. 213 of Java and M2, a vigorous Madras seedling, (b) Co 213, a cross between P. O. J. 213 and Kansar, and (c) Co 214, a cross between green sport of Striped Mauritius and a seedling developed by crossing Saretha with the **Kans** grass. Co 221 and Co 213 are high sugar-yielding varieties and resist drought, hence suitable for dry cultivation where that may be possible. Co 214 gives a smaller tonnage, but the **gur** and sugar made from it are excellent. Other seedling canes, recently imported from Coimbatore for experimental cultivation in Bhopal are, Co 205, Co 210, Co 237, Co 240, Co 281, Co 290 and Co 294. These have all been grown successfully in nurseries or plots of a few square yards in the local farms. All that is known so far about them is that they seem to be remarkably suitable for Malwa conditions.

Field-scale trials have to be made to determine their merits. Most of the Coimbatore seedling canes have, as one of their characteristic peculiarities, proved to be excellent ratooners in the Malwa climate, Co 213 and Co 221 having displayed particularly luxuriant ratoon growth for two successive seasons following a plant crop, though even in this respect S.48, referred to in a subsequent paragraph, surpasses all seedlings, specially when its ratoon crop is treated with Ammonium Sulphate. It has to be seen for how many years more the seedlings now under trial will continue to give satisfactory ratoons.

Exotic and imported varieties grown at Bhopal.

An exotic variety which has been cultivated in Bhopal during the past six or seven years under the name of Lakhapur is apparently a Java seedling of the medium type. It is a very rich cane and produces high class **gur** though somewhat dark in colour, but is liable to Red Rot. The sugar it yields is very white with large crystals. It is probably the original J. 33 of Shahjahanpur which obtained it from Coimbatore, where it was known as a cross between Preanger (a thick Java cane) and **Chan** or **Chin,** the well known thin red cane of Upper India.

A variety, **247B,** having been favourably mentioned by the Indian Sugar Committee as a cane eminently suitable on account of its hard rind and good yield for distribution in districts of the Central Provinces, where cane crops are liable sometimes to serious damage by wild pigs, the seed canes were obtained from one of the Government Farms in the C.P. and grown at Bhopal. According to Noel Deerr this is a Java cane which is a cross between the Canne Morte or Red Fiji (male) and the Cheribon (female). The letter B stands for Bouricius who obtained the cross. It is a tall cane, almost erect, and of good thickness, the colour being dark violet. The internodes are covered with fairly thick wax all over and are cylindrical, the arrangement of the internodes being distinctly zigzag. The shape of the eye is cordiform, the channel above the eye being invisible. It has a sweet juice, ripens late and arrows occasionally. It grows very luxuriantly with good manuring and adequate irrigation in the Bhopal climate, and gives a heavy tonnage, but the juice is not so rich in sucrose as that of Lakhapur, or the best of the Coimbatore seedlings. It is locally known as Madan Mahal.

The following is the result of the analyses made in the Bhopal Laboratory :—

Cane		Brix of juice at 17.5°C
Sucrose	Fibre	
14%–15%	13.5%–14.8%	19.5–20.5

The variety seems to have been very popular in Java. In 1912, as much as 54% of the total cane area was under this variety in that island, but the area fell to 29% in 1919 and 26% in 1920 (Indian Sugar Committee's Report para 24)

One of the exotic thick canes which seems to have a good future for it in the Bhopal climate is the "**Manjav.**" This was originally imported into Manjri in 1914 from West Indies and was supposed to be "B 376." On account of some doubt, however, as to its identity, the local name Manjav was given to it ("Man" from Manjri and "Jav" from Java). The seed canes of this variety were obtained in 1924 from Manjri for cultivation in Bhopal, where it has been grown since. It is an erect cane, not very tall (except when very heavily manured and frequently irrigated). The tillering is medium and the cane does not ordinarily flower in Malwa conditions. It is a late ripener, the colour of the cane being greenish yellow or yellowish green, with an admixture of light shades of blue and pink. The upper half of the cane is more greenish than the lower, even towards the end of the season. The internodes have a light wax over their surface, black incrustations being also present, the stalk is slightly zigzag; the internodes having a slight uniform bulge are nearly cylindrical in appearance. The leaves are almost pale green and never attain the dark green shade characteristic of other thick canes. The juice is very sweet and has usually a high purity. Hence the cane is greatly appreciated locally for chewing. All saccharine products made from the juice are of excellent quality, especially the very light coloured raw mealy sugar (see chapter on **Kachcha Bura**) obtained by crushing the **gur** when boiled to a higher temperature than is customary for **gur**-making. The cane is however not a good ratooner, and, when grown as a plant crop, requires heavy manuring and copious waterings. The yield too is not high compared with other Manjri canes. It is probably the purity of the juice and low percentage of colouring matters in it, which account for the excellence of its products. The sucrose content of the cane in Manjri varied from 13.5 to 14.5 and the fibre from 11 to 11.5 per cent of the cane, the brix degrees at 17.5°C being 19 to 20. The result of the determinations made in Bhopal is:—

Cane		Brix of juice at 17.5°C.
Sucrose	Fibre	
14%–15%	11.5–12.0	19–20.

A striped thick variety most commonly cultivated in Mysore where it is known as **Patta Patti** has been very highly spoken of by the Indian Sugar Committee. According to their Report "its Juice has a very high sugar content, the average being about 19% in addition to 0.5 of glucose. It tillers freely and responds

well to manure, but tends to lodge under good cultivation and high manuring. It was stated to yield from 117 to 136 Mds. of **gur** (per acre) but this is probably the maximum rather than the average range of yield." The seed canes of this variety were obtained from Mysore and tried in Bhopal for three seasons, under the usual system of cultivation followed for thick canes. In the first two, the variety having been found to be very liable to damage by the chilo, the results were disappointing. In the third season (1927) the growth has been better. The variety seems to require very frequent waterings during the summer. No definite opinion can be given as yet regarding its suitability for Malwa, but the account given of it above renders it desirable that exhaustive trials should be made in Malwa. In Bhopal the sucrose content of the cane was found to be 10 to 11 p.c., the fibre 15 to 15.5 p.c. and the Brix degrees of the juice 18 to 19.

Ashy Mauritius, one of the well known exotic canes was tried for several years at the Shahjahanpur Farm where it yielded nearly 106 Mds. of **gur** to the acre, the sucrose content of the cane varying from 12.7 to 13.6 p.c. in average seasons. The purity of the juice was high varying up to 89.7. The variety has been tried at Bhopal with remarkably good results so far as the quality of the white sugar is concerned. In the Bhopal Laboratory the analyses of the cane gave the following results :—

Cane		Brix of juice at 17.5°C
Sucrose, 14.5%	Fibre, 14.0%	20.27

The cane is however said to be very liable to Red Rot which is a weak point. So far it has been free from disease in Bhopal.

Red Mauritius, the seed of which was procured for Bhopal from the Central Provinces also promises well. The white sugar it yielded was excellent. Discussing the improvements in cultivation of cane in the Godavari district, the Director of Agriculture, Madras, has remarked that "Red Mauritius not only gave a yield of fifty tons of cane and over 4½ tons of jaggery per acre but was resistant to a large extent to the Red Rot fungus." From this point of view the variety is deserving of attention from those who wish to grow thick canes, as it is these canes that are most susceptible to damage by the fungus in all parts of India.

The cane which has however done best at Bhopal on the whole is **S. 48,** obtained from Shahjahanpur. Its origin is more or less obscure, but it is certain that it is not one of the seedlings developed at Coimbatore, and has been imported from Java where it was originally developed. Mr. Venkatraman, the Government of

India Sugarcane Expert thinks that there is some probability that it is J. 213 a well known Java cane. S. 48 is a purplish red, tall, hard cane, erect and slightly reclining at full maturity. It tillers and arrows profusely. The bottom internodes are longer than the top ones and are covered with light bloom all over the surface, black incrustations being present below the wax ring here and there. The internodes have a tendency to split though to a less extent than those of Co. 221. The eye-bud is of medium size and the channel distinctly marked and shallow. This variety is reported from Manjri to have yielded 96 standard Mds. of **gur** per acre in 1924–25 and similar or even higher yields have been obtained from it at the Shahjahanpur Farm, as at Bhopal, where it has occupied a very prominent position in the sugar-making experiments carried out. As a ratooner there is no cane to compete with it because of its profuse tillering. Great credit is due to the Shahjahanpur Farm for bringing this cane into prominence. It possesses qualities unsurpassed by any other cane that the author has hitherto used for the manufacture of white sugar in India. It grows without irrigation too in the Bhopal climate and yields **gur** which is most remarkably rich in crystals, and is of distinctly pinkish colour in the earlier part of the season becoming almost white in the latter part, provided the juice is properly clarified and boiled. So far, no specimen of **gur** or **rab** made with an Indian variety can compete with the same product of S. 48 in quality.

A thin variety imported from Shahjahanpur under the name of **A. 42** is a very fine cane for production of **gur.** It is a selection from the Rakhra group of Rohelkhand and is said to have been found originally in the Mohammadi Tahsil of the Kheri district (Oudh).

The best outturns of Lakhapur and S. 48 have varied from 85 to 95 standard maunds of **gur** or **rab** per acre in Bhopal, when grown without heavy manuring. Co 221, Co 213 and Co 214 have yielded up to 93, 79 and 55 standrd maunds of **rab** respectively.

S. 39 (**Yuba**), another variety imported from Shahjahanpur bears the characters of the Pansahi group of U.P. and has yielded over 90 Mds. of **gur** per acre in Bhopal which though light-coloured was not so rich in crystals as that yielded by the seedling canes.

The following exotic varieties, though not yet cultivated at the Bhopal Farms on a field scale, have been grown in nurseries or on plots of a few square yards, in order to produce canes for further propagation. They have done so well under careful treatment that they seem to be deserving of special mention, as the kinds likely to suit the Malwa soil and climate admirably, in addition to those described before and tested repeatedly:—

(1) Cavengerie.

The seed of this cane was obtained from the Manjri Farm. According to Messrs Patel and Patwardhan "this was introduced from Mauritius in 1898, and has become the usual cane of the Western India sea coast." According to the description they have given in Poona Bulletin No. 125 of 1925, it is is an erect, tall, thick, moderately soft cane, has medium tillering capacity, requires 14 to 16 months (in Poona climate) to ripen fully; when grown as a 12 month crop, it seldom or never arrows, but may do so when kept late in the season. It is of a dark wine or greenish red colour and has longitudinal greenish black stripes. The internodes are cylindrical and of medium length. The leaf sheaths are covered with stiff hairs. The colour of the sheath is reddish green and has whitish longitudinal stripes. The composition of the cane as determined at the Manjri Chemical Laboratory and the yield of **gur** obtained at the Manjri Farm are noted below :—

Cane		Juice	Outturn of **gur** per acre		
Sucrose,	Fibre,	Brix at 17.5°C	lbs.	Std. Mds.	Bhopal Mds.
11 to 13%	13 to 15%	16.5 to 18	7965	96.8	80.5

According to Noel Deerr "this cane which must be included amongst the world's standard varieties is also known as Port Mackay under which name it has been extensively cultivated in Mauritius. It affords juice less pure and sweet than that given by Tanna and Cheribon canes, but being of a hardy nature and adapted to colder temperatures is successfully cultivated in the less tropical cane-growing districts and at higher elevations in the more tropical ones."

(2) D 109.

This is one of the Demarara canes. According to Noel Deerr, the stalk is erect and dark purple and the leaf narrow and dark green. "This cane possesses in a marked degree the property of 'going back' that is to say it is very atavistic and in second and third ratoons degenerates into a reed-like growth." It is described in Poona Bulletin No. 125 of 1925 as a tall, reclining, thick, soft, juicy cane which tillers and arrows sparsely and ripens in 11½ to 12 months. Its ratooning is said to have been good at Manjri (but at Bhopal it has not proved to be so). The distinguishing features described in the above publication are:—

"The internodes are more enlarged at the base than at the top. Its peculiar purplish red colour at the lower internodes and purplish yellow in varying shades in the upper internodes is characteristic."

Composition and yield found at Manjri are given below:-

Composition.					**Yield of**
Cane		Juice	**Gur** per acre		
Sucrose, 12.5 to 14 p.c.	Fibre, 11 to 12.5 p.c.	Brix at 17.5°C 17.5 to 18	lbs. 9,025	Std. Mds. 109.7	Bhopal Mds. 91.4

(3) "Java".

The seed canes were obtained for trial in Bhopal from Manjri where the identity of the cane seems to have been somewhat doubtful. This variety came into Manjri from Hebbal in Mysore under the name "Java 100" in 1914. In the Manjri Bulletin referred to above it is stated to be a tall, thick, soft, juicy cane, erect in growth, has medium tillering capacity and does not arrow; it ripens in 11 to 12 months. The colour of the cane is greenish yellow to yellow with reddish or pink colourations on exposed internodes, the stalk being very nearly straight or zigzag. The cane has shown great luxuriance of growth in the nursery at Bhopal. Composition of the cane and the yield of **gur** as determined at the Manjri Farm are as follows:—

Composition.					**Yield of**
Cane		Juice	**Gur** per acre.		
Sucrose, per cent	Fibre, per cent	Brix at 17.5°C	lbs.	Std. Mds.	Bhopal Mds.
14 to 15.5	12 to 13	18.5 to 19	6,526	79.3	66

(4) White Transparent.

This too was imported from Manjri, where it is stated to have been received from the West Indies in 1914. It is called **transparent** probably because of the polished appearance of its skin. According to Noel Deerr the light-coloured variety of the Cheribon canes has been grown extensively in the British West Indies under the name of White Transparent. There are other canes to which the term **transparent** is applied, and they are characterised by a longitudinal channel running upwards from the eye. According to Kruger the White Transparent is grown in Barbados. Mr. Noel Deerr remarks that there, it is presumably the white Cheribon.

He quotes Harrison and Jenman's description of the White Transparent as follows :—

"Canes several, erect, and partly trailing, of full average length, barely of full average girth, colour at first pink, finally a grey horn tinge in the lower part and yellow tinged with pink in the upper half, rarely blotched with carmine when sun exposed. Arrows projected well aloft. Panicles full size, copiously branched and flowered."

White Transparent is described by Mr. Patel of Poona as "a medium tall and thick cane, has a medium tillering capacity, requires from 11½ to 12 months for ripening and arrows profusely. It did not however flower in Bhopal. Its colour is pale yellow to greenish yellow in majority of cases, and in a few cases light pink or blue shade is observed. The internodes have light wax all over the surface and are nearly cylindrical in shape, black incrustations being also present. The channel on the internodes, going upwards from the eye-bud, is narrow and indistinct and extends over two-thirds of the surface of the internode, is broad at the base and is gradually narrowing upwards. In certain cases the channel is well pronounced. The stalk gradually narrows from the base to the top.

The figures showing composition of the cane as determined at Manjri and Bhopal are:—

Cane		Juice	Analysis made at
Sucrose, per cent	Fibre, per cent	Brix at 17.5°C	
15 to 17	11.5 to 13	20 to 21	Manjri
13.66	13.24	20.14	Bhopal

The outturn of **gur** obtained per acre at Manjri was 6,724 lbs *i.e.* 81.8 Standard Maunds or 68.1 Bhopal Maunds.

(5) Waxy Red.

This is the tallest and one of the thickest canes hitherto grown at the Bhopal Farms. The seed canes were obtained from Manjri where its origin is said to be "somewhat obscure." The cane grows to a great height but does not tiller profusely, arrows freely and takes a year to attain maturity, the stalk being continuous not zigzag. The colour of the cane is reddish purple covered with dense bloom or wax all over the surface of the internodes: hence the name. Its chief distinguishing characters are:—

(1) Presence of waxy coat on the entire surface of the internode (2) Shape of the internode cylindrical (3) Presence of black incrustations on the internodes. The composition and yield of the cane according to the Manjri Bulletin referred to above are:—

Composition			**Yield of**		
Cane		Juice	**Gur** per acre		
Sucrose per cent	Fibre per cent	Brix at 17.5°C	lbs.	Std. Mds.	Bhopal Mds.
13.5 to 15	11 to 12	19 to 19.5	6,970	84.7	70.6

Determinations made at Bhopal gave the following figures:—

Sucrose, per cent	Fibre, per cent	Brix at 17.5°C
15.48	11.48	21.41

(6) B. 1528.

This is one of the West Indies canes said to have been imported to Manjri in 1914. It is an erect, (sometimes reclining) tall, thick cane which does not arrow usually, has medium tillering capacity and ripens in 11½ to 12 months. The colour of the cane is "purple in varying intensities." Its internodes are nearly cylindrical in shape and have a light coating of wax with black incrustations on the upper part. The internodes have a bulging at the upper part in some cases but are constricted at the nodes. The stalk is "strongly zigzag." The eye bud is "broad, triangular, ovate and big in size." The channel is prominent, broad, but shallow and extends all over the internodes. These features form the chief distinguishing characters of the cane.

Composition and yield (Manjri figures)

Cane		Juice	Yield of **gur** per acre.		
Sucrose, per cent	Fibre, per cent	Brix at 17.5°C	lbs.	Std Mds.	Bhopal Mds.
13 to 15	11.5 to 12.5	18 to 19	7,761	94.4	78.6

(7) B. 208.

This is one of the Barbados (West Indies) canes reported from Manjri to have been imported in 1914. In Bhopal the seed canes were obtained from Manjri. Mr. Noel Deerr's description of the cane is as follows:—

"Stalk: erect, green, with peculiar swellings at many nodes. Leaf: Vertical, dark green. Eye: Prominent, inclining to sprout. This cane is extraordinarily subject to environment, in some places being of great merit and in others valueless; it is unsuited for heavy clays, is of great saccharine strength and is reported to be drought-resisting; it is also subject to variation."

It is an erect thick cane of medium height (5 to 7 feet at Manjri; same in Bhopal) varying from 1¼ to 1½ inches in diameter and having a green or bottle-green colour which may even be described as "Mango-green." The main distinguishing character noted in the Manjri Bulletin is "the distinct tumerous appearance on the opposite side of the bud."

Composition and yield as determined at Manjri are:—

Cane		Juice	Yield of **gur** per acre.		
Sucrose, per cent	Fibre, per cent	Brix at 17.5°C	lbs.	Std. Mds.	Bhopal Mds.
14 to 16	11.5 to 13.5	19.5 to 20.5	5,928	71.8	59.8

Although this cane seems to be richest in sucrose amongst those reported from Manjri, except perhaps the White Transparent, the average outturn determined there is the lowest, as it has been at Bhopal. The reason lies probably in its unsuitability (as Mr. Noel Deerr says) for heavy soils, as black soils usually are.

The analysis made at Bhopal gave the following figures:

Cane		Brix of juice at 17.5°C
Sucrose, per cent	Fibre, per cent	
16.0	10.11	20.64

(8) H. M. 544.

This cane has been mentioned as "H. M. 544" in Poona Bulletin No. 125 of 1925, but a correction slip issued since its publication shows that the correct name is "H. M. 310.' It is reported to have been imported into Manjri from Habbal, Mysore, in 1920. From the figures of outturn quoted in the Bulletin it appears that this variety has given the largest yield both of cane and **gur** amongst those tried at the Manjri Farm, the weight of **gur** obtained per acre there, having been 9,098 lbs. *i.e.* 110.6 Standard or 92.2 Bhopal Maunds in 1924-25.

So far little is known about its sugar-yielding merits under Malwa conditions, beyond the fact that it has grown thoroughly well in the Bhopal nursery and seems to be suited to the climate of this part of India—hence deserving of attention on the part of those interested in the local cane husbandry, for which reason it is being mentioned at this early stage.

It is stated in the above Bulletin to be "a tall, thick, erect. cane, has a medium tillering capacity, does not arrow and requires from 12 to 12½ months to ripen. The colour of the cane is yellow or greenish yellow, where exposed, pink or purplish colour developes due to exposure or partial removal of sheaths. The internodes are slightly more enlarged at the base than at the top, nearly cylindrical in shape, wax on the surface of internodes is absent, stalk is slightly zigzag, black incrustations are present." The eye-bud is "medium in size oval to ovate in shape." The channel "is mostly absent and in exceptionally rare cases it extends over half the surface of the internodes."

The composition of the cane reported from Manjri is:.—

Cane		Juice
Sucrose, per cent	Fibre, per cent	Brix at 17.5°C
12 to 13	12.5 to 13	17.5 to 18

(9) H. M. 600.

This cane too was obtained from Habbal, Mysore, in 1920 for trial at the Manjri Farm, whence it was imported and grown in the Bhopal nursery. Here its growth has been quite satisfactory. Although the yield of this cane has not been so heavy at Manjri as that of the Habbal cane just described, it is classed there as one of the good canes having yielded 92.5 Standard (77 Bhopal) Maunds of **gur** to the acre in 1924-25 which is about three times the average outturn obtained from the indigenous canes of Bhopal. On this account the variety should not be lost sight of by the cane-growers of Malwa. The following is a summary of the description of the cane given by the Manjri Farm authorities:—

The stalk is "erect in earlier stages reclining at full maturity." It is a "tall thick variety having excellent vigour in mother canes: it tillers rather less than the average and requires 11½ to 12 months to ripen." The colour "varies from dirty greenish yellow with a shade of dirty black to purplish or crimson. In general it is dirty greenish yellow with a blackish brown shade." The internodes are long, "sides of the internodes are not in a straight line and are bulging irregularly." The stalk is zigzag and has light wax on the surface of the internodes and black incrustations." The eye-bud is hemispherical with flattened top and the channel is absent.

Composition as determined at Manjri.

Cane		Juice
Sucrose, per cent	Fibre, per cent	Brix at 17.5°C
12 to 12.75	12.5 to 13	17 to 17.5

Recent importations from Coimbatore include two of the highly-prized canes of Java viz: E. K. 28 and P. O. J. 100, both of which have been grown successfully in the Bhopal nursery. Little is known to the author about the merits of these canes under Indian conditions, but their value can be easily gauged from the fact that, according to the Indian Sugar Committee's Report, 32% of the total cane area in Java was planted with E. K. 28 in 1920 and 16% with P. O. J. 100. Java which at present commands the Indian Sugar market would not favour any but the finest varieties. For this reason alone, all concerned in India with the improvement of the Industry would be well advised to test these canes in the various cane-growing tracts of the country, specially in Malwa where conditions seem to be particularly favourable to the growth of superior varieties. The author cannot find a published description of E. K. 28. Even Mr. Noel Deerr did not describe it in the edition of his book "Cane Sugar" published in 1911, unless it be under some other name.

As to P. O. J. 100, the variety is according to that authority "a cross between a black Borneo cane and an unknown father." The colour of this cane is "golden to light brown with fiery red sun-burnt patches." There is wax "in a ring under the nodes." The shape of the internodes is cylindrical and the arrangement of the internodes "faintly zigzag." The eye is "oval when young, somewhat swollen or prominent later." The channel above the eye is "distinct on two-thirds of the internodes." It is "an upright, rather short cane, very sweet, ripens early and arrows profusely.

THE NURSERY SYSTEM

Knowing, as we do now, that seedling canes are capable of yielding 2 to 3 times as much sugar per acre in Bhopal as the local varieties, if not more, the desirability of quick replacement of the latter by the former is obvious. But considering the heavy expense involved in importing seed canes from Shahjahanpur, Coimbatore or other Government Farms far away from Malwa, which have after all got only a limited supply for issue, it would take a very long time and considerable outlay to introduce and extend the cultivation of the new varieties in Malwa. As a solution of this difficulty the following may be suggested as a possible plan based on the experience gained in Java under what is known as the Nursery System.

Cane should be sown early in the usual way in the ordinary season. When the plants are about 6 months old and have formed 3 to 4 joints the stems may be cut up into sets each having 2 to 3 buds in it. These sets may be planted in June after the advent of the Monsoon rains, and it will probably be found that about 6 times the original area could be planted up in this manner. The newly-planted sets should be allowed to grow from June to the following January, when they will once again give sets for planting. These should be planted again in January, and in the next December the crop should be ready for harvest or for further propagation. By this method any variety may possibly be multiplied about 36 times in one and 216 times in two years. The method is said to have been tried successfully at Pusa, but probably has not yet been given a trial in Central India.

Plants resulting from this mode of cultivation are stated to be more vigorous, and when cut up for propagation purposes give better germination than the ordinary sets, because the sets of the former kind are immature and always germinate better than the mature ones, owing to the fact that immature canes contain more glucose and salts. Fungus diseases of the cane develop most when the cane is attaining maturity. By above method disease-free material is obtained. If a field is attacked with red rot, the above method might prove useful for checking the spread of the disease in the succeeding crop.

The above plan might, if it proved a practical success, open the way for rapid extension of superior cane varieties in the sugar-cane producing areas of Malwa, where the indigenous kinds have by investigation been found to be markedly poor in sucrose contents, but where the soil and climate are eminently fitted for some of the best of sugar-yielding canes known in India.

For an account of the experience gained at Pusa in the above method of propagation, the reader may refer to page 148 Vol. XX Part II of the Agricultural Journal of India.

CHAPTER V.

Cultivation of sugarcane in Bhopal.

Sugarcane is cultivated in Bhopal for the most part as an irrigated crop but, to a limited extent, the crop is also grown without irrigation, the latter system being hitherto confined practically to the more humid tracts of the Eastern part of the State where the physical character of the soil makes it particularly retentive of moisture and easier for tillage operations. The total area under cane is only 0.27 per cent of the normal cultivated area, the area under dry cultivation being 9 per cent of the total cane area. In view of the fact that there is abundance of suitable soil in the State and that under proper cultivation sugarcane thrives remarkably well, the casual observer, taking only a superficial view of things, is likely to feel surprised at the slow progress made in extending the cultivation of the crop. A glance at the indigenous methods of cultivation will, however, soon convince him that the defects in the methods employed are mainly responsible for the slackness in the advance. One of the chief handicaps is the large number of successive waterings which the irrigation system of cultivation inevitably demands. It is this feature of the work which owing to its irksome nature greatly discourages the cane-grower and deters him from launching out upon any large scale. Once this labour of watering is substantially reduced, there would soon be a rapid and substantial increase in the cane area.

Cultivation with irrigation under the indigenous system.

The following is a description of the operations as carried on in the typical cane tract of the Western district of the State which is noted for its luxuriance of cane growth and a good outturn of raw sugar.

Preparation of the ground.

Sugarcane generally follows a **rabi** (spring) crop. When the latter has been removed, the land is allowed to remain fallow till about a month before the advent of the monsoon rains, when the surface soil is stirred once with the **bakkhar.** Cattle manure, one year old, is spread evenly on the ground by hand, in quantities varying from 5 to 15 cart-loads per **bigha,** according to the means of the cultivator. The cart load is 6 to 8 local maunds and the **bigha** is 7/10th of an acre. The application of manure in greater quantities than the above, in the richer class of soils, results in a rank growth which injuriously affects the quality of the **gur** produced, as in that case it is too soft to fetch a proper price. The manure is incorporated

with the soil by running the **bakkhar** cross-wise over the field so that it may not be washed away by the first monsoon showers. When the rain sets in and the soil is fit for ploughing, **sanai** (Crotalaria Juncea) is sown broadcast at the rate of 30 local seers (about 75 lbs) to the **bigha** and mixed up with the soil by working a **bakkhar** behind. The field is then levelled by running the **bakkhar** with its wooden body upside down. Nothing more is done till the middle of August when ordinarily the **sanai** crop is ready to be used for green-manuring (**Sanchur**). The tender plants are pulled up by hand each stem is broken into two and the green material spread over the field and allowed to rot. In a fortnight or so, depending on the weather conditions,the rotted material is ploughed in. As the material generally offers some resistance to the ploughing operation, it takes the ordinary country plough about two days to plough the **bigha.** After four or five days the land is ploughed cross-wise, and this operation also takes about two days per **bigha** for the same reason. Thereafter about seven more ploughings are given at intervals up to the month of Katik (October). If clods are formed, as is often the case, they are broken and pulverised by working the implement known as "Swar" two or three times over the field. The "Swar" is a heavy log of wood drawn by four bullocks led by two field labourers. Green-manuring is believed to exercise a beneficial effect on the crop as regards both the quality and the yield of the **gur**.

Planting. The times of planting varies greatly, ranging from October to January or even later, and is chosen with reference to weather conditions and the convenience of the cultivator. If the monsoon rains cease early, and the tillage operations have been completed by September, the cane crop is planted in October soon after sowing of wheat is over. If, however, the rains continue till October and the cultivator is busy otherwise, the planting is delayed to the end of November which is generally regarded as the usual time. It is not uncommon to plant the crop in December and January, but few cultivators wait longer than this, though with proper tillage and timely irrigations the later crops thrive as well as those sown early. With early sowing the young plants are sufficiently forward before the arrival of the hot weather to resist the heat better, and the crop thus requires less frequent waterings. But on the other hand, if there are high winds during the rains, the plants are beaten down and loss results that way, for the **gur** produced is seriously affected both in quality and quantity. If, however, planting is unduly delayed, the growth in the hot weather is more or less stunted as a result of the heat (unless copious waterings are frequently resorted to) and the yield is usually low. Under normal conditions early maturity follows early planting and late sown crops are not ripe enough for crushing until February.

One or two days before planting, the furrows called **"Batars"** are opened with the country plough $1\frac{1}{2}$ feet apart from each other, one plough finishing a **bigha** of land during the day.

For the purpose of planting, canes free from disease are selected from a plant or a ratoon crop and are stripped of their leaves by the hand in such a way as to protect the buds from damage. The top leaves (not the part containing any portion of the cane) are cut away with a sickle (the **Hansia**). The dry leaves, if allowed to remain on the internodes, are supposed to favour attack by white-ants and are therefore carefully removed. Three to five thousand whole canes are necessary to plant a **bigha** (7/10ths of an acre) the number depending upon the length of canes. The price of seed canes varies from Rs. 5/- to Rs. 7/- per 1000 canes according to their length and thickness and from 10 to 12 men for one day are required for cutting and stripping the seed canes sufficient to plant a **bigha.**

The **Charas** (self-emptying leather-bucket) is used as a rule to draw the water necessary for planting. The soil being well prepared and rendered porous by laborious tillage soaks an abundance of moisture at this stage. A driver with two pairs of bullocks is therefore employed at the well to ensure a continuous and adequate supply of water. Four labourers are located in the field, one for laying the whole canes in the furrows, two for pressing them down with feet into the furrows when watered, and one to attend to the course of the water channel. The canes are buried into the ground by the pressure of the feet and are covered up with mud in the course of the operation. It is not customary to cut up the cane into sets for planting purposes or to employ the tops as is the rule in Rohelkhand and the Western districts of the United Provinces.

Subsequent operations. Ten days after planting, when the field is fairly dry, the country plough with a plank of wood tied to its share is worked between the furrows in which the seed canes were planted. A new furrow is thus opened between the original furrows carrying the seed canes, and the earth raised during the operation is pushed by the plank of wood so as to cover up the seed canes entirely. One plough per **bigha** per day represents the cost of this operation. This being done, the field is divided into irrigation beds (**Kiyara**) by blocking up the course of two adjacent furrows at about every six feet leaving a third one to be used as the usual irrigation channel (**Barha**). It requires four men per **bigha** per day to prepare the beds with the spades (**Phaora**).

When the **kiyaras** are ready, seedlings of garlic or onion or both mixed are planted along the sides of the cane rows. Coriander seed is also broadcasted thin all over the field, these operations requiring five or six men per **bigha** per day. The subsidiary crops grow with the cane and require successive waterings, at least three being given every month. Weeding and hoeing are done with the **khurpi** altogethcr half a dozen times before the commencement of the hot weather in March, when the subsidiary crops are harvested. The number of labourers required for the first weeding is about 20 per **bigha** per day, but the number decreases as the operation is repeated, the last weeding being completed only by five persons. Two to four labourers suffice for harvesting the coriander crop and about 8 for the garlic or onion. If the extra crops are not raised, only two waterings every month may prove sufficient during the cold weather, but three or four are usually needed during the hot weather months.

After removal of the subsidiary crops, the cane crop receives a good supply of water and as soon as the land is in a fit condition to be dug with spade (**Phaora**), the plants are earthed up, 10 labourers per **bigha** per day being required to complete the work. These men, however, have to be paid wages at the high rate of 8 annas a day, as this work has to be done at the same time as the **rabi** harvest when labour for other field operations is hard to get.

If sufficient water is not available in the hot season, the field has to be covered up with green leaves and twigs of **Khankhar** or **Dhak** (Butea Frondosa) to protect the growing plants against the effect of immoderate heat. In the month of June, when the monsoon rains are near, there is again a natural growth of weeds which are cleared off, 8 to 10 labourers per **bigha** per day being employed. With the advent of the monsoon rains the irrigation is stopped. By this time the total number of waterings given may have amounted to 25 or even 30 or more, the frequency varying with the nature of the soil and the season. From November to March it generally takes two days for one leather-bucket (**charas**) to irrigate a **bigha** and from April onwards about 3 days on an average. In the particular tract the practices of which we are describing, the depth from which water has to be lifted varies from 12 to 20 feet up to the end of March, and thereafter the water level gradually goes down to a depth ranging from 25 to 30 feet.

After the **rabi** harvest, when there are no green crops on the ground except sugarcane, great care has to be taken to protect the latter against the attack of wild animals especially the deer, the hare and the wild boar. A watchman is therefore usually employed at Rs. 2/- per mensem to scare these enemies away, specially during the night. At the commencement of the rains, when rapid

growth begins, the number of watchmen is increased to two, each getting Rs. 2/- per mensem, and these are kept on till the harvest. The crop is weeded once in July, about 15 men per **bigha** per day being required, and once more in August when about 12 labourers suffice. On the cessation of the monsoon rains irrigation is again resorted to, the number of waterings varying from 2 to 3 according as the crop is harvested early or late.

Harvesting. Canes are cut with a small hatchet close to the ground and stripped of their leaves by the hand with a sickle (the **Hansia**). It is customary to pay Re 1/- for this operation according to the variety for the following quantities :—

Munhtora.		16,000	canes.
Mandkia.	10,000 to	12,000	canes.
Bhelsai.	Do.	Do.	Do.

The labourers stripping the canes get in addition, 3 seers of **gur** for every rupee paid in cash and also the green shoots of the canes. The tops which are cut by the owner of the crop are utilised by him for feeding his cattle. The stripper can deal with 1,000 to 1,200 canes per day and collects from one to two head-loads of green shoots which he either uses for feeding his own bullocks or which he sells for 2½ or 3 annas. Stripping is done generally by boys and girls or women, men joining in only when they have no other work to do.

The clean canes are then crushed ordinarily by a three-roller iron mill and the juice is boiled mostly into **gur** and occasionally into **rab.**

Ratooning. When the cane crop has been harvested, the aftermath is capable under proper treatment of yielding an average crop in the succeeding season, though, of course, it is usually inferior to its predecessor. Advantage is generally taken of this habit in the growth of sugarcane. The dry leaves (trash) left in the field at the harvest time are removed and the field watered. The weeds are removed with the **khurpi** and the soil stirred with the same instrument. Three or four waterings are given at suitable intervals. When water has permeated deep into the ground and the surface is fairly dry, the soil is dug up with the spade (**phaora**). Irrigation is kept up, as necessity arises, till the commencement of the monsoon rain. From June to August the crop is weeded once a month, as in the case of the plant crop. From February to June the crop is watched at night by one man, and during the rainy season two watchmen are employed to watch each **bigha.** Altogether 16 waterings are given during the year;

6 from February to March, 8 from April to June and 2 after the rainy season. It is not the practice to grow any subsidiary crops with a ratoon cane crop. The **Munhtora** and **Mandkia** varieties yield only one decent ratoon crop while the **Bhelsai** is capable of giving 2 such crops and therefore is preferred to the other varieties.

Rotation. The system of rotation generally followed is as given below :—

Year	Crop.
1st year	..Sugarcane plant crop.
2nd year	.. Do.
3rd year	..Ratoon crop.
4th year	..**Sanai** (Crotalaria Juncea) grown for fibre or seed during the rains, and then **Masur** (Ervum Lens) during the **rabi** season.
5th year	..Rice during the rains and then Tiura (Lathyrus Sativus) or Masur (Ervum Lens) during the **rabi** season.
6th year	..**Sanai** (Crotalaria Juncea) for green manuring during the rains followed by sugarcane during the **rabi** season.

Cost of Cultivation per Bigha. (7/10ths of an acre) of plant crop.

	Rs. a. p.	Rs. a. p.
Running the first **bakkhar** before the rains: one **bakkhar** for half the day.. ..		0 8 0
Application of cattle manure, 10 cartloads, Price	2 8 0	7 4 0
Cart hire	3 0 0	
Digging and loading of manure at the manure pit; 2 men per day for 3 days ..	1 8 0	
Spreading of manure; one man	0 4 0	

Cost of cultivation per Bigha. (7/10ths of an acre) of plant crop

	Rs. a. p.	Rs. a. p.
Cross cultivation with the **bakkhar** for mixing up the manure: one **bakkhar** for half the day..		0 8 0
Sowing **sanai** for green manuring :—		
Seed, 30 seers	3 0 0	
Broadcasting, one man	0 4 0	
Ploughing to mix the seed with the soil: one plough	1 0 0	4 6 0
Levelling the land with the **bakkhar** (share turned over): one **bakkhar** for an hour ..	0 2 0	
Pulling up the **sanai** plants, breaking and spreading them over the field (seven men).		1 12 0
One ploughing for mixing up the decomposed green manure with the soil, 2 ploughs for one day		2 0 0
One cross-ploughing for the same (2 ploughs)		2 0 0
7 further ploughings for preparing the field, 7 ploughs for one day		7 0 0
Opening furrows (**Batars**) for planting cane, one plough for one day		1 0 0
Cost of seed canes 4,000 @ Rs. 6/- per 1,000		24 0 0
Cutting and stripping seed canes (12 men)		3 0 0

Planting :—

	Rs. a. p.	Rs. a. p.
One **charas** (Leather-bucket). requiring two pairs of bullocks to work the well for 3 days	6 0 0	
4 men in the field for planting for three days	3 0 0	9 0 0
Opening furrows between every two rows of seed canes and covering up seed canes with earth with a plough, one plough ..		1 0 0
Making water-beds with **phaoras**, 4 men ..		1 0 0
Cost of garlic or onion seedlings and coriander seed :—		
Garlic or onion seedlings	1 0 0	
Coriander seed..	0 2 0	1 2 0
Planting garlic or onion seedlings and broadcasting coriander seed (6 men) ..		1 8 0

	Rs. a. p.	Rs. a. p.
Fencing :—		
Cost of material, labour, etc.		20 3 0
6 weedings and hceings before the garlic etc. are harvested, :—		
1st (20 persons)	5 0 0	
2nd (10 Do.)	2 8 0	
3rd (8 Do.)	2 0 0	
4th (6 persons)	1 8 0	13 8 0
5th (5 persons)	1 4 0	
6th (5 persons)	1 4 0	
Harvesting garlic (8 men)		2 0 0
Harvesting coriander (2 men)		0 8 0
Digging with the **phaoras** and raising earth round the plants after the garlic etc., have been harvested (10 men at 8 annas each)..		5 0 0
Weeding in June (8 men)		2 0 0
Irrigation :-		
Charas hire for 64 days for 26 waterings, at Re. 1 per day :—		
November or December to March, 12 waterings (24 days)		
April to June, 12 waterings at 3 days per watering (36 days)..		
After rains, 2 waterings at 2 days per watering (4 days)		
Total 64 days.		64 0 0
Wages of one man for 64 days for guiding water in the field		16 0 0
Night-Watching :—		
From April to June, 1 man	6 0 0	34 0 0
From July to January, 2 men	28 0 0	
Weeding in July (15 men)		3 12 0
Do. in August (12 men)		3 0 0
To carpenter, 3 seers of **gur** for setting up the water-lift		0 12 0
Land rent for 2 years		12 0 0
To **Chamar,** 5 seers 4 chhattaks of **gur** for repairing the **charas**		1 5 0
	Total Rs.	245 0 0

Cost of Cultivation per bigha of ratoon crop.

	Rs. a. p.	Rs. a. p.
Clearing of trash, 2 men		0 8 0
Weeding and stirring the soil with the **khurpi** after first watering, 10 men ..		2 8 0
Digging the soil with **phaoras** to make it loose when it gets consolidated after three or four waterings, (12 men)		3 0 0
Weeding just before rains, (8 men).. ..		2 0 0
Weeding in the month of July, (15 men)		3 12 0
Weeding in the month of August, (12 men)		3 0 0
Waterings (14) :—		
Phagun and Chait		
(March and April) (4)..	8 0 0	
Baisakh and Jeth		
(May and June) (8)	24 0 0	39 8 0
After the rains (2)	4 0 0	
Wages of 1 man for 14 days for guiding water	3 8 0	
Fencing. Repairs to the previous year's fence		5 0 0
Night-Watching.		
One man from **Phagun** to **Jeth** at Rs. 2/- per mensem	8 0 0	36 0 0
2 men from **Asarh** to **Pus** Rs. 2/- each per mensem	28 0 0	
Land rent		6 0 0
To carpenter, 3 seers of **gur** for setting up the water-lift		0 12
To **Chamar**, 5 seers 4 chhattaks of **gur** for repairing the **charas**		1 5
Total Rs.		103 5 0

CHAPTER VI.

Manufacture of gur and rab as practised by the Bhopal cultivator.

The usual practice with the tenants is to work with only one 3-roller mill and one flat-bottomed iron pan having a slanting side wall, placed on a furnace or oven which is merely a round pit dug in the ground about 6 feet deep. The diameter of the pit at the top, on which the pan rests, is about 2 feet 10 inches, with the sides sloping inwards to the bottom, where the diameter is about 5 feet. On one side of this pit, usually on the north side, another excavation is made to a depth of about 1 foot above the bottom level of the first pit in which the fuel is stored and the fire-man sits for feeding the furnace through a feed-hole about a foot broad and 15 inches high in the wall of the first pit.

The pan is 3 feet 5 inches in diameter at the top and 2 feet 8 inches at the bottom with sloping sides. It holds 76 Bhopal Seers of juice together with 5 seers of water at a time. That is to say, the capacity of the pan is about 200 lbs.

The mill is worked day and night, using 2 good pairs of bullocks by turns. There are three sets each of two men who work the mill. One set works from morning to evening and two sets during the night, the night men working only 6 hours.

Milling. The mill is fixed in a pit, the whole of it being under the ground level, save for the part to which the driving shaft is attached. The pit is sufficiently capacious to hold the mill and to have enough room to carry a large bundle of canes and to accommodate the man who feeds the cane to the mill. The expressed juice flows into a receptacle which is usually a round earthen vessel capable of holding about 10 seers of juice. When this vessel is full, it is emptied into a large earthen storage vessel (**Nand**) kept at a little distance from the milling pit. Usually 8 charges of the smaller vessel poured into the **nand** make one charge for the pan. When the full charge of juice has been received in the **nand,** it is transferred to the pan; the **nand** is again filled with juice from the mill, and so the work goes on day and night until the whole crop of the tenant has been used. The **nands** and the juice pots at the foot of the mill are never changed unless they break by accident, nor are they cleaned in any way beyond a single washing with plain water, unless a perceptible collection of scum or fine mill refuse is noticed sticking in them. The crushing is generally done in the open yard under the full sun, and the canes for the milling and the **nand** for the storage of juice are all allowed to remain in the sun, with the result that the **nand** and the earthen

receptacles give out a disagreeable acetic smell after a couple of days' work. This feature of the work injuriously affects the quality of the jaggery to a very appreciable extent. No care, however, is taken to avoid this evil.

Boiling. When sufficient juice (about 190 lbs) has been received in the **nand,** it is transferred to the boiling pan by straining through a thickly woven basket which catches only the large pieces of bagasse allowing the fine particles to pass through into the pan. Then about 10 lbs of water is poured over the basket with the object of washing down into the pan any sweet juice adhering to the basket and pieces of the bagasse. The fire is then started up, using as fuel, during the first two or three days, only **khankhari** or the dry twigs and leaves of **khankhar** (Butea Frondosa) which are collected for the purpose beforehand, and thereafter as soon as the bagasse is sufficiently dry the latter is used, mixed up with the **khankhari.** One cartload, of **khankhari** is required, on an average, for a day's work. As the heat in the furnace increases, the scum rises to the surface of the juice in the pan, but it is not removed unless it is very thick, which is the case when the juice comes from "lodged" or diseased canes. The fireman does not as a rule attend very regularly to the furnace, for during the course of boiling, he may stop firing at will, sometimes for a full hour and allow the juice to boil slowly or simmer, which affects the quality of the resulting product very seriously. When frothing commences, the pan-man allays it by fanning the syrup with the iron **pauna** (a thin perforated iron disc to which a handle is attached). When the pan is nearly ready, the condition is ascertained by a small quantity of the syrup being poured into a cup of water. If it solidifies into a little ball showing the requisite hardness when pressed between the thumb and a finger, the pan is taken down from the furnace by two men and placed on a heap of wet bagasse, and the mass stirred for a time to induce cooling. The pan is then tilted in order to pour the contents on to the **chakara** or **chak.** If tilted direct on the **chak** without cooling in this manner, the mass will swell up and it will thus overflow; the granulation will be bad and the **gur** will be sticky. The **chak** is a round unbaked earthen receptacle, about 3 feet in diameter with a rim about 6 inches high, made of mud specially prepared by mixing earth with a large quantity of chopped straw or horse dung and well worked up to make it sufficiently hard. The mass in the **chak** is stirred with an iron **khurpi** (scraper) at intervals to favour cooling and granulation. When the condition is right the mass is scraped into a heap to keep it hot and slices are taken off the heap and made into balls of about two **chhattaks** each in weight. If the mass does not solidify to the required degree so as to be made into balls, which is the case when the juice is from lodged or diseased canes, it is stored in

a semi-liquid condition in earthen pots and is called **rab.** Thus the **rab** made by the cultivator is usually the poor product prepared from damaged canes, which contains very little crystallisable sugar and is sticky. The work of firing, boiling, making balls of **gur** and potting the **rab** is all managed by the fireman and the boiler between them. It is seldom that the mill men help them. After the charge has been transferred from the pan to the **chak,** the pan is put back again on to the furnace and a fresh supply of juice poured into it from the **nand.** The fireman, while he is busy manipulating the mass of the previous charge with the panman, occasionally goes and puts a little fuel into the furnace. The process of boiling is thus rendered very slow and objectionable, the output being seven to nine charges per 24 hours representing 175 to 225 lbs of **gur,** the average being 200 lbs.

The cost of boiling. A **bigha** of sugarcane crop of average quality will take about 10 days to be boiled and will require the following material and services :—

	Rs. A. Ps.	Rs. A. P.
10 cartloads of **khankhari** fuel (Butea frondosa)		
Cutting the twigs	4 0 0	
Cart hire	3 8 0	10 0 0
Royalty..	2 8 0	
Making furnace and store-thatch will cost about Rs. 4/, and as the tenant usually has 2 **bighas** of cane crop, the cost spread over 2 **bighas** comes to		2 0 0
2 pairs of bullocks daily for 10 days ..		25 0 0
4 men working during the day (2 on the furnace and 2 on the mill) for 10 days at 5 annas a day each		12 8 0
8 men working during the night for 10 days at 3 annas each per day		15 0 0
Lamp oil for 10 days		0 15 0
Lubricating oil for 10 days		0 12 6
Cutting and stripping of canes, average number per **bigha** being 64,000 at 16,000 per rupee		4 0 0
Mill hire for 10 days..		10 0 0
	Total. Rs.	80—3—6

Expense of gur in kind.

		Mds.	Srs.	Chs.
		BHOPAL WEIGHT.		
(1).	To cane strippers at 3 seers for every rupee they get in cash	0	12	0
(2).	To 8 men working in the night at 6 chhattaks for each man daily for 10 days	0	30	0
(3).	To **Bhangi** (sweeper), 8 chhattaks daily for cleaning the dung and litter of the bullocks	0	5	0
(4).	To carpenter (8, chhattaks daily and four chhattaks every alternate day when he makes his visit to the mill, average 10 chhattaks per day)	0	6	4
(5).	To the mill owner	0	5	0
(6).	To the blacksmith, 10 chhattaks per day	0	6	4
(7).	To the potter, (7 chhattaks daily) for supplying **chak** and other mud pots	0	4	6
(8).	To **Balahi** (the village watchman), 2 seers of **gur** and the extra ball (**bheli**) for every day the mill is at work	0	3	4
(9).	To **Nai** (the village barber) ..	0	1	8
(10).	To **Dhobi** (the village washerman)	0	2	0
(11).	To **Brahmin** (the family priest) ..	0	2	0
(12).	To **Rao Bhat** (the village bard) ..	0	1	0
(13).	To temple	0	3	0
(14).	Canes consumed, juice drunk and **gur** eaten by workmen (on whom there is no check or restriction, they being allowed to eat such quantity as they like) and also by their friends will be equivalent to 2 maunds of **gur** approximately. The general idea is that nearly 20 to 25 per cent of the total produce of the crop is consumed in kind altogether.	1	38	6
	Total	4	0	0

A tenant usually grows 2 **bighas** of sugarcane, therefore the consumption and expense of the **gur** are to be divided as below :—

		Mds.	Srs.	Chs.
(a).	Expense proper on one **bigha** ..	1	28	14
(b).	Expense divisible by 2, it being common to the whole crop of two bighas (2.11.2)	1	5	9
	Thus the total expense of **gur** on one **bigha** of each corp is ..	2	34	7

The price or value of this **gur** at about 4 seers per rupee is Rs. 28.10.0.

Therefore the total cost per **bigha** is :—	Rs.	A.	P.
Cultivation	245	0	0
Manufacture	80	3	6
Paid in kind	28	10	0
Total Rs.	353–	13—	6
Equivalent to Rs.	353.84		

The yield of **gur** per acre, as has been actually determined by crop cutting experiments, is as follows :—

	According to Bhopal weight			According to Standard weight.		
	Mds.	Srs.	Chs.	Mds.	Srs.	Chs.
Munhtora cane	29	0	0	34	32	0
Mandkia cane	31	20	0	37	32	0
Bhelsai cane	36	10	0	43	20	0

The value of the above is calculated as follows :—

Variety of cane from which the **gur** was made	Weight in Bhopal maunds.			Value.		
	Mds.	Srs.	Chs.	Rs.	a.	p.
Munhtora	29	0	0	290	0	0
Mandkia	31	20	0	252	0	0
Bhelsai	36	10	0	290	0	0

The value of **Munhtora gur** is taken at Rs. 10 per Bhopal Md. and that of other canes at Rs. 8 per Md.

Reduced to the **Bigha** of Bhopal the yield in each case will be as follows :—

Variety of cane	Weight of **gur** according to Bhopal Mds.	Weight of **gur** according to Standard Mds.	Weight of **gur** in lbs.
Munhtora.	20.38	24.46	2,012
Mandkia.	22.14	26.57	2,185
Bhelsai	25.48	30.58	2,515
Total.	68.0	81.61	6,712

The average of all the three varieties if sown mixed, as is often done, will be as follows ;—

Weight according to Bhopal Mds.	Weight according to Standard Mds.	Weight in lbs.	Average value in rupees at Rs. 9 per Bhopal maund.
68 divided by 3 = 22.66	81.61 divided by 3 = 27.2	6,712 divided by 3 = 2,237	Rs. 203.94

Add to above the value of the produce of garlic and coriander ; 4 maunds garlic (Rs. 25/-), 20 seers coriander (Rs. 5/-) ..	Rs. 30 0 0
Total cost of cultivation and manufacture per **bigha** as given on page 47	Rs.353.84

Value of sugarcane crop	Rs. 203.94
Value of garlic and other crops	Rs. 30.00
Debit balance (loss)	Rs. 119.90
Total	Rs. 353.84

The produce from a ratoon crop is said to be 2/3rds of the plant crop. Therefore the cost of manufacturing **gur** from a ratoon crop per **bigha** will be two-thirds of the cost of the plant crop, which was :—

		Rs.	a.	p.
Cost of manufacture paid in cash ...		80	3	6
Cost of manufacture paid in kind ...		28	10	0
	Total	108	13	6
Two-thirds of this is		72	9	0
Add the cost of cultivation of the ratoon crop		103	5	0
	Total cost	175	14	0
	Equivalent to	175.87		

The value realised from a **bigha** of ratoon crop will also be two-thirds of the value of plant crop, nearly two-thirds of Rs. 203.94 (see page 48) or Rs. 135.96, leaving a debit balance on ratoon crop of Rs. 39.91.

Taking the plant and ratoon crops together the figures indicate the following results:—

Total cost per bigha :—		**Total receipts per bigha :—**	
Plant crop.	Rs. 353.84	**Gur** from plant crop	Rs. 203.94
Ratoon do	Rs. 175.87	**Gur** from ratoon crop	Rs. 135.96
		Garlic and subsidiary crops	Rs. 30.00
		Debit balance (loss)...	Rs. 159.81
	Rs. 529.71		Rs. 529.71

The above observations make it clear that the cost of cultivation and manufacture calculated at the rates of wages current in the villages renders the cane grower's business distinctly unremunerative at present. That is really the reason which deters many a cultivator and materially hinders the progress towards extension of the cane area. The question naturally arises why the cultivator grows cane at all under the existing conditions. The causes are not far to seek. For the social life of the village **gur** which is the only form of sugar which can be made available easily is indispensable. The cultivator needs occupation for himself, his family and bullocks during the **khali fasl** (April to June) and by growing canes he finds employment for all of them at a time when otherwise he would be sitting idle. He does not ordinarily employ hired labour except when it is essential to do so, and uses mostly the resources of his own family, to whose credit the wages which would be otherwise paid to the professional labourers should be reckoned. The greater part of the wages calculated in the above accounts must be treated as saved to the family and thus is an indirect gain to it. Sugar-growing improves the cultivator's status in the village and increases his influence and popularity, as by growing cane he can afford to invite his neighbours to co-operate with him and to enjoy a generous treat to the produce. He acquires the position of an employer instead of one of an employee, and lastly he finds himself in possession of a crop which he can readily use as security for taking a loan from the shrewd and exacting local money-lender, should it be necessary for such purposes as the expenses of a marriage or death in the family or even for an agricultural improvement.

These are the conditions and inducements which control the existence of the **gur**-producing industry in Bhopal, and the industry is in a very struggling and poor condition to-day. There is, however, no reason why with superior canes and better methods of cultivation and manufacture, the industry should not become one of the most remunerative agricultural occupations in the State. Educative work on the part of the State authorities is wanted towards which a start has already been made by practical demonstrations.

CHAPTER VII.

Improvements in the methods of cultivation with irrigation.

A. THE PLANT CROP.

No system of agriculture in Malwa needs more drastic changes than the methods of growing sugarcane, but the local conditions are such that none of the methods followed in other parts of India, including those developed at Shahjahanpur and Manjri, can be imitated without substantial modifications to suit those conditions. The following methods likely to be most suitable have been evolved after careful observation, in course of four seasons, of the progress made by cane crops grown in different fields under different old and modern methods :—

The general belief that cane can be grown successfully only after a fallow (**Bahan**) of 6 or 7 months, bare or green, as is the custom, has by repeated trials proved to be entirely erroneous. The **Kharik** system of the United Provinces in which the cane follows the autumn **Urd** (Phaseolus radiatus) or the **Chana** (Cicer Arietinum) immediately, has been found to be equally successful in Bhopal, and the cultivator, if he wishes to do so, need not deprive himself of a **Kharif** crop or even the **Rabi** crop of gram for the sake of cane. If the cultivator wants to follow the **Bahan** system, which undoubtedly gives a better return, he should, in the first instance, look to the manure supply at his disposal. If this is abundant and the varieties to be selected for cultivation are the superior medium or thick canes, such as, S.48, Co 221, Co 213, Manjav and P. O. J. 33, about 300 to 400 standard maunds of cattle dung should be spread over every acre of the selected **Rabi** stubble, stirred previously with the **Bakkhar,** soon after removal of the **Rabi** crop, and the land well irrigated. Thoroughly rotten manure is better, but if this is not available the supply collected during the winter may be applied with or without older material. As soon as the land is fairly dry, it should be ploughed deep, preferably with an iron soil-inverting plough, and cross-ploughed with the same, in order to turn the roots over and incorporate the manure. The land should then be levelled with the **patela** immediately, to prevent formation of clods. Until the arrival of the monsoon rain it should be cultivated with the **Bakkhar** twice a month and oftener, if convenient. Soon after the first shower of monsoon rain, the land should be ploughed and cross-ploughed again with a deep soil-inverting plough, but the use of the **patela** should be avoided at this stage to enable the furrows opened to receive and retain the rain water. During the rainy season the land is generally too sticky to admit of ploughing, but the cultivator should be careful to watch his opportunity

for giving further ploughing during the rains. He will find that at least after every long break the soil is in a condition which would render ploughing possible. Such an opportunity should always be availed of with punctuality. The number of ploughings during the rains will thus depend on the weather conditions and the cultivator's industry.

If, however, the cultivator does not possess or cannot procure sufficient manure in the beginning of the hot weather, there will be two courses open to him viz: (1) that he should lay out trenches across his field about 10" deep and 3 to 4 feet apart from centre to centre, according as his crop is to be one of a medium cane or of a thick variety, the wider interspaces being necessary in the latter case. During the hot weather and the rainy season these trenches should be filled up gradually with fresh manure, dung, urine, litter, ashes and sweepings from his cattle shed and his hut. As dung cakes (**Kandas** or **Uplas**) can not be made for fuel purposes during the rains, the cane grower will have no difficulty in purchasing fresh cattle dung for a nominal price from his brother cultivators in the village who do not generally require manure, being accustomed mostly to dry **rabi** cultivation requiring no cattle manure. The supply commanded by himself can thus be supplemented adequately from bought manure. The field should be embanked properly in order to prevent the cattle manure being washed away by drainage during the rains. In the beginning of the cold weather the manure in the trenches should be stirred frequently with an indigenous plough, and the blank spaces between the trenches ploughed deep with an iron plough and levelled with the **patela.** When the time for planting arrives, the manured trenches should be used as seed bed. Excellent crops have been raised in this manner at the main Experimental Farm in Bhopal. (2) That he must resort to green-manuring, and for this purpose instead of moistening the land by artificial irrigation after removal of the **rabi** crop, he should start by cultivating the stubble with the **Bakkhar** and repeat that operation as often as convenient, not less than once a fortnight, and broadcast **sanai** (Crotalaria Juncea) seed thickly, at the rate of about 100 to 150 lbs. to the acre, as soon as the monsoon conditions declare themselves. The green leguminous crop should be allowed to grow till it is fit to be ploughed in, which is generally the case about the beginning or the middle of August. It should then be ploughed in with a soil-inverting plough, such as the Turn Wrest, or the Watt's, or one of the Kirloskar's ploughs, and a cross-ploughing should be given immediately after. In an unusually wet rainy season such as was experienced in Bhopal in 1926, if the soil is not fit for ploughing by the middle of August, the crop of Crotalaria should be pulled up by the hands, spread on the land and

pressed down with the feet, so as to be thoroughly mixed with the wet soil, and be decomposed by the end of September. In Bhopal a green crop of **san** hemp supplied about 90 Bhopal maunds or 108 standard maunds of green organic matter. The green matter was not analysed but assuming it to have contained 0·4 per cent of Nitrogen (as analyses of the material made in other parts of India have shown) the amount of Nitrogen supplied to the soil by this source calculates to 35.5 lbs. of Nitrogen per acre which is about 30 per cent of the supply required by a normal cane crop. If weather conditions permit, one or more ploughings with an **improved** or the country plough should be given in September. In both cases described above, that is to say whether the land has been kept bare-fallow or green-fallow during the rains, frequent ploughings by country plough followed by levelling the land with the **patela** and by cultivating it with the **Bakkhar** should be done.

In November trenches should be made in the land thoroughly prepared in the above manner. On account of scarcity of labour it is very difficult to have this done with the **Kassi** or **Kudali** by hand power, as is the practice in Shahjahanpur. It has also proved too expensive an operation in Malwa conditions to be recommended, and it would be necessary to adopt a ridging plough to do the work. Although the cost is high, it is essential and will prove economical in the long run. The American "No. 19 Chattanooga Ridging Plough" 10" size, having a chilled mould-board, price Rs. 60/-, has been found useful in the Bhopal experiments. It goes nearly eight inches deep and makes trenches 2 ft. to 2ft. 4 inches wide. As each trench should be above two feet in width, the ridging plough should be run from one end of the field to the other and back again along the same furrow, so as to make the trench wide and deep enough. This implement may be used with advantage to make trenches 3 to 3½ feet apart, if the cane selected for cultivation is a medium cane, and 4 feet apart, if it is a thick cane e.g. Lakhapur (P.O.J. 33) or the Manjav. If extra thick canes such as White Transparent and Waxy Red are to be grown the trenches should be wider, about 5 feet apart. Investigators in other parts of India have, on the basis of their experience, recommended 4 feet as the most suitable distance from centre to centre for making trenches when cultivation of medium canes is intended. It is very difficult to make the Malwa cultivator believe that such a practice could be economical, though as a matter of fact it is. In each trench should follow a heavy plough of the make and size of the local **"Nagar"** to loosen the furrows and render them still deeper. A depth of about 10½ to 11 inches may thus be attained in each trench. If sufficient manure was applied in April, it will not be necessary to make a further application at this stage, but if the land has been only manured

with green organic matter during the rain, it should be supplemented with an additional supply of cattle manure at the rate of 100 to 150 standard maunds to the acre. The extra supply should be spread only in the trenches and mixed with the soil by running a country plough in the trenches. It would be well to irrigate the trenches at this stage, and when the soil in the trenches is sufficiently dry, to plough it up with a country plough, and then leave them alone till the time of planting. If the extra manuring is unnecessary, which would be the case when the land has been kept bare-fallow, irrigation would serve no useful purpose, and the trenches should be left to weather till the planting is commenced. The value of castor cake as a nitrogenous manure beneficial to the cane crop has been fully established by repeated trials at Shahjahanpur and other Experimental Farms in India, where it is used in quantities varying from 20 to 40 maunds per acre without or in addition to the farmyard manure. It contains about 4.5 per cent of nitrogen in an available form. This material is however not on the market in the Bhopal territory at present, but if a demand crops up among the local cultivators who would be well advised to adopt the use of it, supply is bound to follow. The only oilcake obtainable at a reasonable cost in the local bazars is that of Rameli (Guizatia Abyssinica) an oil seed largely grown in Malwa. This stuff has never been tried at the Bhopal Farms and no definite opinion can therefore be given on its manurial value as compared with that of castor cake. There is however no doubt that the Rameli cake contains nitrogen, an ingredient known to benefit the cane. It would be well for the local cultivator therefore to try the only cake easily obtainable locally for purposes of manure. **Kanji** cake is also available to a smaller extent in the local market and is known to benefit the cane crop.

Mr. Ritchie, Deputy Director of Agriculture, Northern Circle, C.P., has mentioned a successful method of preparing organic manure for sugarcane in the shape of a compost which he says is "every bit as good as farmyard manure, if not better" (page 37 of the Agricultural Journal of India Vol. XXI, Part I, January 1926).

The compost should be prepared from **Cassia Tora,** called **Tarota** in C.P., **Panwar** in Bhopal and **Chakaund** or **Chakonr** in Oudh, cut from the village site, fallow lands, road side areas and field embankments, and all other weeds and **kachra** removed from fields in weeding.

The weeds should be collected and stored in a heap and allowed to decompose. After three or four months the heap should be turned to admit of better decomposition, and kept for two years in order to allow any weed seeds to germinate in the succeeding monsoon, and so, prevent the reinfestation of the field. If earlier

decomposition is aimed at, the weeds should be stored in layers of one foot thickness, one over the other, each layer being sprinkled over with lime. If the latter is available it would seem preferable to use it.

Mr. Ritchie carried out experiments in 1920-21 with three different varieties of sugarcane to compare the relative value of farmyard manure and the compost, the following results having been obtained :—

Sugarcane		Standard Maunds per acre	lbs. **gur** per acre	Standard maunds **gur** per acre
Paunda	Cattle dung	250	5818	70.0
	Compost	250	6545	79.6
Yuba	Cattle dung	250	6560	79.8
	Compost	250	6720	81.7
Gilman's	Cattle dung	250	6000	72.9
Red Sport	Compost	250	7000	85.1

It is stated by the same officer that "one plot of non-experimental **khari** cane was heavily manured with compost in order to fill up some uneven parts in the field and the outturn was at the rate of 52 tons of stripped cane per acre." This is about 4 times the average yield obtained from the indigenous canes commonly grown by the Bhopal cultivator.

The value of this method of conserving weeds for manurial purposes is thus too obvious to need comment. The Malwa cultivators would be well advised to adopt it as a suitable measure for producing valuable manure from a source hitherto neglected.

Of artificial mineral manures only ammonium sulphate has been tried in Bhopal and found to stimulate the growth in a marked degree. It has been applied in two instalments, first at the time of planting in February and then when the plants are ridged up in May or June. As to the good effect of the manure there is not the slightest doubt, but experiments have not yet reached the stage when it would be possible to pronounce an opinion as to the financial results of its use. About 7½ standard maunds of this manure should be applied to the acre, if no farmyard manure has been used and less in proportion if it has been used.

In Java this manure is used in quantities varying from 5 to 6½ Standard maunds (80 to 110 lbs of Nitrogen) per acre, the applications varying in quantity with the degree of natural fertility of the field.

The Indian Sugar Committee have stated that an application of 120 lbs. of Nitrogen (which is equivalent to about 600 of Ammonium Sulphate) per acre to a field which is given proper cultivation and suitable irrigation should result in an outturn of 800 maunds (about 30 tons) of improved cane per acre in Upper India, (vide page 221 para 234 of the Committee's Report). Experiments made in Bhopal have shown that an equally good or even a higher yield may be obtained in Central India with liberal application of Ammonium Sulphate. According to experiments made in Shahjahanpur as much as 150 lbs of nitrogen per acre may with advantage be applied to medium canes.

It is already well known that the bulk of the farmyard manure available in India is utilised for fuel, Malwa being no exception, in spite of the fact that an abundance of forests yielding firewood exists in the tract. There is no prospect of the practice being abandoned within the near future. The question therefore strikes the thinking mind at once, how the additional supply of nitrogenous manure essential for successful cultivation of superior canes can be obtained, if increased production is to be attempted. The carts in common use in Malwa are small and the expense of carting cattle manure from neighbouring villages, even where a moderate supply is possible, is usually high. Green manuring with **Sanai** (Crotalaria Juncea) only supplies about one third of the normal requirements of an average crop of exotic and Coimbatore canes. The balance, it is not quite easy to supplement from the local supply of farmyard manure ordinarily available. The provision of a cheap supply of some nitrogenous fertiliser is therefore a problem of special importance for the Indian cane husbandry, especially in Malwa, where cake meals are scarce. The only manurial agent which forces itself on our attention is ammonium sulphate, which is fortunately manufactured in India, but unfortunately not utilised in the country to the extent it deserves.

Sulphate of Ammonia is obtained in India as a by-product in the manufacture of coke in the coal and iron working districts of Behar and Bengal, but the produce is largely exported to Java, Japan and the Straits Settlement.

Before the Great European War, the quantity produced annually was small, not exceeding 3,500 tons of which only 1000 tons were consumed in the country, mainly by the European planters, and the rest exported. In 1921 the estimated production on the Indian Coal Fields was 8,000 tons, and the Indian Sugar Committee was then of opinion, on the basis of trustworthy data furnished to it, that by 1926 the production would rise to 20,000 tons. Exports to Java alone rose from 853 tons in 1922 to 3,012 tons in 1924. During the war export of Sulphate of Ammonia from

Great Britain was prohibited. There was, therefore, greater demand in Java for the Indian product and this led to rise in its price in India. The value of the manure as a fertiliser for the sugarcane crop can be easily gauged from the fact that from over 35 to over 45 thousand tons of ammonium sulphate have been imported annually by Java alone from Great Britain and nearly 43 thousand tons from the United States in addition. The continuous increase in the demand for artificial nitrogenous fertilisers, so essentially needed in cane producing countries, has resulted in the development, in European countries, of processes for obtaining sulphate of ammonia from the unlimited supply of nitrogen in the air, by synthetic means, which, the Indian Sugar Committee were of opinion, would threaten severe competition with the by-product sulphate of ammonia industry. That is one of the strong reasons for the Indian cane-grower patronising, in the true **Swadeshi** spirit, the Indian Ammonium Sulphate industry by contributing towards increased consumption of the fertiliser for manurial purposes, in India.

The Indian Sugar Committee have expressed it as their well-considered opinion that "so long as sugar does not fall below Rs. 15 per maund (82.2 lbs), the cane grower can profitably buy sulphate of ammonia at Rs. 315 per ton" or about Rs. 11/8 per standard maund. As a matter of fact however sulphate of ammonia can be landed anywhere in Malwa at a cost varying from Rs. 7/8 to Rs. 8/8 per standard maund.

When it is considered that sulphate of ammonia contains about 20 per cent of nitrogen, while castor cake which should contain on an average from 5 to 5½ per cent of nitrogen and costs about Rs. 5 per standard maund or more, if imported from Upper India, the great cheapness of sulphate of ammonia will be easy to realise.

The Sugar Bureau at Pusa took steps to introduce this fertiliser 3 or 4 years ago in North Behar and the indications were that large cane-growers had then begun to appreciate its use as a manure. Mr. Sayer of the Pusa Institute has remarked that "two cwts. of this manure given per acre at the break of the rains where cane is grown without irrigation, produces striking results", (page 397 Vol. XX Part V of the Agricultural Journal of India for September 1925). Favourable results of its fertilising effects on sugarcane have been reported from the Punjab, while in Bhopal it has been observed that a field of second ratoon crop treated with 400 lbs. of the manure produced as good a crop as a plant crop obtained from the usual manuring with cattle dung, if not better. Mr. Venkatraman, the Sugarcane Expert to the Government of India writing to the author regarding ammonium sulphate informed him that he had "found it particularly useful in

pulling up a backward crop." It is also noteworthy that among inorganic artificial manures, it is only sulphate of ammonia which produces a sufficiently heavy tonnage when used singly, that is to say, not in conjunction with other organic manures, and this is the greatest recommendation in its favour, saving as it does, on account of its concentrated nature, the heavy cartage of bulky material and the trouble of procuring manure from different villages, perhaps not within easy reach, which would otherwise be inevitable. This seems to be the main reason for the general use of ammonium sulphate in the Java cane husbandry.

It will thus be to the advantage of the Malwa capitalists to establish suitable centres for the supply of this useful fertiliser, and of the cane producer to lose no time in introducing its use. A season's trial under normal conditions will open his eyes.

Poudrette which contains about 0.9 per cent of nitrogen is a very valuable manure for sugarcane specially for the medium and thick varieties and where available should be applied in preference to the ordinary farmyard manure, which may contain about 0.6 per cent of nitrogen. In the United Provinces this manure is largely used for the cultivation of thick canes grown mainly for chewing purposes. As much as 800 standard maunds are sometimes applied to the acre, 500 maunds being the ordinary limit.

It must, however, be remembered that over-manuring usually results in luxuriant vegetative growth of the plants and delays ripening; and although a very high tonnage may be obtained thereby at the end of the normal crushing season, the juice will be poor in sucrose and all forms of sugar made from it are bound to be very inferior in quality. Therefore, if cane is grown for the purpose of manufacture of sugar, as distinguished from that of chewing, the manuring must be judicious and should not exceed the limits of moderation.

When cane is to succeed a crop of **Urd,** the land should be watered soon after that crop has been harvested, manured, ploughed again and again, and cultivated otherwise. The trenches should be made, as in the other case, with a ridging plough, soon after the ploughings are over and made ready for planting. If cane is to follow an early crop of gram, the latter should be harvested sometime during latter half of February, and the land watered, manured ploughed over and over again, and levelled with the **patela,** trenches being made before the middle of March.

Although it must be admitted that under the **bahan** system early sowing in November and December is very advantageous, yet the necessity for frequent waterings and the expense and trouble involved therein are so great, that the advantages do not

counterbalance the necessary additional outlay and labour, and the expected increase in the outturn is hardly commensurate with that in the expenditure. During the cold weather the germination is, as a rule, very slow indeed and it usually takes two or three waterings before the plants are fairly up on the ground. Till this happens, the cultivator cannot afford to take rest, or devote himself to any agricultural work other than irrigating the cane crop. The practice of sowing the crop so early as is customary in Malwa may certainly be given up with impunity except where the Chilo Simplex is known to be a persistent enemy, making its appearance usually in April, when the main stems of the late sown crops are generally too tender to resist the insect's attack. The author's experience is that in areas not infested with the borer, crops planted from the middle of February to the middle of March or even somewhat later, grow quite as luxuriantly in the long run as those planted much earlier, and with a remarkably less cost of irrigation, which means considerable relief to the cultivator, his relations and his live-stock. He need not therefore be in too great a hurry about planting the new crop, until the cane crushing and **gur** making operations, relating to his standing crop of the previous growth, are well advanced. One great advantage of postponing the planting till this stage is, that the tops removed from the canes employed for crushing will be available for planting purposes, and the need for cutting up the whole canes into sets will be entirely removed. The whole of his standing crop will be available for crushing with the exception of the tops, which, if crushed, will injuriously affect the quality of his **gur,** owing to the high glucose content. By cutting the top off, seed will be available in quantities sufficient to grow a larger area than that of the field yielding the tops, and the yield of the **gur** will materially improve in quality. The cultivator will get the seed without having to pay for it and the saving will be substantial. The advantage to the cultivator is thus two-fold. During the **gur** making season, which is at its height from the middle of January to that of February the tops, each about 15″ to 18″ in length and bearing not less than 3 buds at the nodes, should, as they are removed from the canes meant for crushing while they are being stripped of their leaves, be collected, and tied together in bundles of convenient size with twisted green leaves of the cane. These bundles should be placed vertically in an oblong excavation made in a convenient corner of the field and covered over with leaves and earth, which should be moistened with water from time to time in order to help germination of the buds in the pit. Each day's collection of the tops should be preserved daily in the pit which is called **bijgara,** and care should be taken not to place the bundles long in the sun, or horizontally at the bottom of the pit, so as to prevent the root system working its way into the bottom soil, and to keep the earth in the pit soft and moist. The

system, though new to Bhopal, is common in the Rohelkhand and Meerut Divisions of the United Provinces, and when followed in Bhopal, with imported and seedling canes, has yielded excellent results. A further advantage of maintaining the store pit is, that when the gaps are noticed in the rows, on completion of the germination of the planted crop, fresh seed will be readily available for filling them up. In actual practice it is found a month or six weeks after planting that in spite of bestowing every care upon selection of the cuttings, some of the buds have failed to germinate. At this stage there is ordinarily no cane standing, and, but for the store in the pit, it would be impossible to fill up the bare patches. Planting should be started between the end of January and the middle of February in the **bahan** fields and carried on rapidly. The store pit should be opened and bundles only sufficient for the day's planting should be taken out. It will be found that by this time most of the buds have perceptibly germinated. Those that have not so germinated, or have dried up, or have otherwise been damaged, for instance as a result of injury caused by the **Hansia** (sickle) in course of stripping of the dry leaves, or of cutting the tops, should be carefully sorted out and discarded. The healthy tops should then be planted with the hand carefully, in such a manner that none of the three buds touches the bottom of the trench. As the position of the buds is naturally alternate along the cutting, it is quite easy to place it so on the bottom surface of the furrow that the situation of one of the three buds may be on the one side of the furrow and of the other two buds along the other side of it. This being done, the seed cuttings should be covered over with three or four inches of earth sliced from the ridges. There should be some loose soil of the depth of two or three inches under the cutting so planted. Irrigation should follow immediately and should be copious.

Under the **Kharik** system the planting should not commence before the beginning of March and may be continued till the end of that month, ample time being taken before March to carry out the operations necessary for securing a good tilth. Under this system too the method of planting should be the same as for **Bahan.**

As soon as the soil of the watered seed bed is fairly dry, it should be hoed lightly with the **Kudali** or **Kassi,** great care being, however, taken not to injure the buds down below. The hoeing helps soil aeration and preservation of moisture in the lower stratum and obviates the necessity of frequent irrigation. If the first watering done at the time of planting does not suffice to bring about good germination within three weeks, as it generally does not, it would be necessary to give the second watering without

further delay. This should again be followed by a careful hoeing. Under favourable seasonal conditions the young crop will not require third watering for about two weeks after the second. At this stage weeds may spring up. If so, the field should be cleared up. Usually the **Pihka, Kansua,** or **Illi** (Chilo Simplex) makes its appearance about this time, the larva burrowing into the main stem which dries up. There is really no effective remedy for this trouble, once the insect pest has begun its ravages, and although the main stem is always lost as a result of its attack, the situation can, in a great measure, be saved by watering the crop copiously in order to favour early tillering of the young plants and enable the injured crop to recover its vigour to a certain extent. Professor Knight remarked in his report on the Manjri Agricultural Station for 1912-13 that, "this was the most serious pest in the surrounding cane cultivation. The planting of maize in the cane has been found to be a very successful remedy in lessening the severity of the attack." The suggested plan may be tried.

Kerosene emulsion prepared by dissolving the ordinary bazar soap in water or in a decoction of dry stems of the tobacco plant stripped of the leaves, and mixing the solution with an equal volume of kerosene oil, if injected by a small glass syringe into the holes caused by pulling out the withered part of the young cane plants, effectively kills the young larvae and extension of the damage is thus appreciably checked, but the operation is too tedious and troublesome to be recommended as a measure of practical utility.

It is noteworthy that crops planted early i.e. during the month of January whose vegetative growth is naturally more advanced at the commencement of the warm weather, when the ravage of the insect usually begins, are far less liable to the attacks of the borer than those planted later.

Careful observations have shown that crops sown in the middle of March, or later, are, owing to the tenderness of the stems far more susceptible to injury from the pest than the more advanced crops of earlier planting. It has also been observed that some cane-growing tracts are more infested with the pest than others, while some are singularly free from it.

Late sown crops can be saved from material damage by this insect only by stimulating the growth with frequent waterings. Therefore in localities where the pest is known to cause damage every year, and it is necessary to grow cane, it would be wise to finish the planting as early as possible - even in December - so as to give the crop a chance of acquiring sufficient vigour by the time of the insect's appearance to resist the attack. In such

localities when the crop, which the cane is to succeed, is off the ground, it would be well to start preparation of the ground for cane by stirring the land with the **Bakkhar,** then spreading it over with dry grass leaves and twigs and setting them on fire, so as to kill all insects. Even with these precautions it would be a prudent measure to resort to early planting in order to minimise the chances of damage from this great enemy of the cane crop.

It is also noteworthy that the ratoon crops suffer little or no damage from the attacks of the borer, owing obviously to the fact that the stems become too strong during their growth in the cold weather to be bored by the pest. A plant crop damaged by the Chilo generally yields a higher tonnage when allowed to ratoon, provided the cultivation is properly looked after and the ratoon crop is watered about once a month until the rains set in.

Under ordinary conditions the need for the fourth watering should arise 3 to 4 weeks later, and for the 5th, not long before the rain. The 6th watering may be required in June if the monsoon holds off, or it may not be wanted at all. It may be that in a particularly dry summer a 7th or even 8th watering may be needed before the rain, but that would be only in exceptionally hot years. Ordinarily 6 to 7 waterings should prove quite sufficient before the rains for medium canes, some of which need less irrigation than others, Co 213 and Co 214 having been found to require the least number of waterings, about 5 only. S.48 and Yuba demand more.

The thick varieties such as P.O.J. 33 (Lakhapur), Manjav and the local white Paunda, however, demand more copious and frequent irrigation without which they do not thrive. In their case it would be advantageous to water the crops twice a month or even three times. The cultivator should be able by experience and observation to decide when his crop, whether of a thick or of a medium variety, must be watered, the commonest indication of the need being the stage when the top point of the leaf blade begins to turn pale and shows signs of wilting or losing freshness and strength.

Late sown crops must, as a rule, be watered at shorter intervals than those planted early.

Sometimes the **mahawat** rain is received in February and an occasional fall in May or in the beginning of June is not rare. Each good shower before the monsoon would mean the saving of one irrigation to the cultivator. Each watering should be followed by one hoeing at least, and the field should be scrupulously kept clean of weeds. In June when the monsoon rain is ordinarily

expected, the plants should be well earthed up before the rains start, otherwise this operation, which is of much importance in order to prevent "lodging" of the crops, may be seriously hindered, as the land when wet is very difficult to work. This operation should be taken up and finished in good time.

During the rainy season the crop would require little attention beyond weeding, when that may be practicable. As the imported canes usually grow very tall, they should be tied in clusters to help and maintain their erect growth. This should be done with green cane leaves, twisted to form a sort of rope. If the monsoon rains continue till October, as they sometimes do, there will be no necessity for another watering, but if the rains cease early, it will be advantageous to give the final watering in that month, as soon as the crop begins to show the need for one. When a crop has been so watered, it should not be harvested for at least 15 days after the irrigation. It is especially noteworthy, that the watering done at the commencement of the winter, benefits the succeeding ratoon crop in a most marked degree.

By adopting the above methods the heavy cost of cultivation now incurred by the cultivator will be very considerably reduced. The need for planting part of the crop, which would, with better advantage, be utilised for **gur**-making, will disappear, and the number of waterings will be reduced from about 30 or so to say about 7 or 8 in the case of medium canes, and about 10 or 11 in that of thick varieties. The bullock labour thus liberated would enable the cultivator to command with the same resources about three to four times the area he is able at present to cope with.

B. The Ratoon Crop.

Among the indigenous canes **Dhaul** (the **Agaul** or **Digchan** of the U. P.) has proved an excellent ratooner. The variety known locally as the **Bhelsai** is either identical with the **Dhaul** or a cane of the same group, and yields an equally fine ratoon crop. Among the imported kinds Yuba (S. 39 of Shahjahanpur) does remarkably well, if left to ratoon. But even as a ratooner S. 48 is second to none, while Co 213, Co 221 and Co 214 are by no means poor ratooners. Indeed Co 221 has proved a very valuable variety for ratooning purposes. Co 214 is a great drought-resister under local conditions, and its roots throw off healthy shoots even when irrigation is started as late as in April and continued during May and June, and these shoots subsequently form good average specimens of cane, if the rains are opportune and normal. In recent trials Co 213 has proved itself to be the best yielder of a ratoon crop, and an admirable resistant of heat, among the Coimbatore canes grown so far. In Bhopal the thick canes, P.O.J. 33 (Lakhapur) and Manjav have both yielded very fair ratoon crops

when the latter were watered every three weeks or so during the hot season and hoed after each watering, no manure being applied. Portions of such crops which happened to be irrigated more frequently flourished still better. The conclusion therefore is that while manure is not an absolute necessity even for the thick canes in the ratoon growth, frequent irrigation is the governing factor, so far as luxuriant growth and the outturn are concerned.

If it is decided to take a ratoon crop, it would be desirable to irrigate the plant crop about 2 to 3 weeks before the commencement of the crushing. As has been stated already, this watering benefits the following ratoon in a very marked degree. But whether this last irrigation has been given to the plant crop or not, the stubble should be burnt soon after the first crop has been harvested and a plentiful supply of water run over the field. When the land is dry, the spaces between the rows of the cane should be ploughed up with the country plough or dug with the **kassi,** the former plan being generally more convenient and much cheaper. A few days after the operation, an abundance of young shoots should make their appearance. Blanks in the rows should be filled by digging the soil with the **kudali** and putting fresh sets in, which may be cuttings from a standing cane or top sets from the store pit. The growth of the crop should be watched, and as soon as the need for the second watering is seen, it should be supplied. The field should then be hoed with the **kudali** or the **khurpi** and again a few days later. About three to four waterings during the hot weather should prove sufficient to keep the crop in good condition until the commencement of the rainy season during which no waterings are required, but more should be given with advantage if possible. With the advent of the monsoon rain the crop should be thoroughly hoed and the plants earthed up. Ratoons are far less liable to attack by the Chilo, as by the time the insect usually appears the plants are, as a rule, well advanced, and strong enough to resist the attack. If an attack comes off, the damage done is small. Manuring always proves beneficial, but is not essential. Should manure be available for the ratoon crop, which is seldom the case, as all manure supply is usually utilised by the cultivator for the new first crop, it should be applied before one of the hot weather waterings, preferably the last one. Sulphate of Ammonia should, if available, be applied some time during the hot weather, the quantity depending upon the condition and vigour of the crop. When the first crop has been generously treated with organic manure or sulphate of ammonia or both, the succeeding ratoon will appear to need no fresh application of the mineral fertiliser. The method of application should be to dig small holes with the **kudali** or **khurpi** close to the stools, fill them with the sulphate and cover them up, or to spread the manure along the stools and incorporate it with the soil by means of the

kudali and then run water along the spaces between the rows. Under these methods a very fair acreage outturn of **gur** or sugar of quite as good a quality as from a plant crop will be insured, though probably the quantity obtained will be less, if manure has not been applied, or the crop has not been sufficiently watered during the hot season. Usually ratoon canes are less juicy than those of the first crop and their rind is harder. S. 48, Co 213 and Co 221 tiller very profusely while ratooning, provided the stubble is irrigated with due regularity. As many as 25 fully developed ratoon canes have been counted in stools which produced only half a dozen canes in the first crop. Under liberal irrigation S. 39 displays similar luxuriance of ratoon growth.

Among the indigenous canes the **kinara** of Rohelkhand and the Hemja of Gorakhpur have, besides the local **Dhaul** and **Bhelsani,** shown special aptitude for successful ratoon cultivation, though very susceptible to damage by the borer, but the injury caused is more than re-compensated by development of fresh shoots in abundance, but similar aptitude is generally wanting in all thick canes which usually refuse to tiller freely even under best treatment, when left to ratoon.

It is to be regretted that owing to the urgent necessity of devoting special attention to the extending cultivation of plant crops at the State farms, and of employing the ratoon canes for seed purposes and for determination of their sugar contents, juice extraction, juice purity, etc., it has been impossible so far, except on a very small scale in one or two cases, to determine the acreage outturn of **gur** or **rab** from the ratoon crops, which were available, and reliable figures cannot therefore be given at this stage. The indications however are that under proper agricultural treatment at least S. 48, Co 205, Co 210, Co 281 and Co 221 would give as heavy a ratoon as a plant crop. It is now certain that a second ratoon crop and even a third may profitably be obtained under Malwa conditions, with adequate manuring and judicious irrigation, and experiments are now in progress with a view to obtaining definite results on these points.

The possibilities for ratoon cultivation of these seedling canes in Malwa are, however, obvious as they are likely to yield crops of nearly the same value as the mother crop but only at half the cost and with less care and attention. On this account too, it is highly desirable to introduce these varieties freely into the local cane husbandry, and to enlighten the cultivator on the economy of the ratooning system which although known to him, is not freely practised because of the unsuitability and the habit of growth of the local varieties he is familiar with.

Cost of improved cultivation.

A. The plant crop.

It remains now to consider the financial aspects of the suggested improvements, and the relation between the cost of cultivation and the yield under the indigenous methods employed for growing local canes, and the improved methods advocated for producing the superior imported canes and Coimbatore seedlings. In preparing the subjoined table showing expenses under the different improved systems of cultivation the wages and cost of materials have been calculated at the same rates as in chapter V which deals with the old indigenous methods, and every operation that high class intensive cultivation demands has been provided for. Materials not within easy reach of the cultivator such as concentrated manures, have not been included in the programme of cultivation.

Statement showing cost of intensive cultivation of sugarcane **per acre** under four different systems,

Operations.	Cost under bare-fallow system (**bahan**)	Cost under green-fallow system (**Sanchur**)	Cost under **Kharik** system (after harvesting **Urd** crop)	Cost under **Kharik** system (after harvesting gram crop)
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
1. Grubbing the land with the **Bakkhar** (once in barefallow, and five times in green-fallow system up to the advent of rain)	1 2 0	5 10 0	Nil	Nil
2. Manuring land with 400 standard maunds of cattle manure equivalent to 60 cartloads of Bhopal. Price of manure Rs. 15. Cart hire Rs. 18. Digging and loading Rs. 9. Spreading Rs. 1/8.	43 8 0	Nil	Nil	Nil
3. Mixing manure with the soil by the **Bakkhar**	0 12 0	Nil	Nil	Nil

Operations.	Cost under **bare-fallow** system (**bahan**)	Cost under green-fallow system (**Sanchur**)	Cost under **Kharik** system (after harvesting **Urd** crop)	Cost under **Kharik** system (after harvesting gram crop)
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A P.
4. Irrigation before ploughing	6 4 0	Nil	5 0 0	5 0 0
5. Manuring with 150 maunds of cattle dung just after watering in the **Kharik** system.	Nil	Nil	16 4 0	16 4 0
6. Ploughing and cross-ploughing with a soil inverting iron plough	3 0 0	Nil	Nil	Nil
7. Ploughing with C. T. plough at Rs. 9 per plough.	Nil	Nil	18 0 0	18 0 0
8. Levelling land with **patela** (flat beam) ..	0 8 0	Nil	Nil	Nil
9. Cultivating land with the **Bakkhar** 3 times during May and June	2 4 0	Nil	Nil	Nil
10. Ploughing and cross-ploughing with C. T. plough after the rains have set in. Two pairs of bullocks and labourers per day for 8 days.	18 0 0	Nil	Nil	Nil
11. Broadcasting **sanai** seed 150 lbs. Price of seed Rs. 4-8, Broadcasting Re. 0-1-0. ...	Nil	4 9 0	Nil	Nil
12. Covering **sanai** seed up with the **Bakkhar**...	Nil	0 12 0	Nil	Nil

Operations	Cost under bare-fallow system (**bahan**)	Cost under green-fallow system (**Sanchur**)	Cost under **Kharik** system (after harvesting) **Urd** crop)	Cost under **Kharik** system (after harvesting gram crop)
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
13. Ploughing in green **sanai** plants in August with C.T. plough. Two pairs of bullocks and 3 labourers for 4 days.	Nil	9 0 0	Nil	Nil
14. Cultivation with the **Bakkhar** after ploughing the green crop. ..	Nil	0 12 0	Nil	Nil
15. Ploughing and cross-ploughing after green manuring during the rainy season ..	Nil	3 0 0	Nil	Nil
16. Two ploughings and two cross-ploughings with country plough after rainy season followed by the **patela** and the **Bakkhar** each time (one ploughing Re. 1/8/- one **patela** Re. 0/8/- & one **Bakkhar** Re. 0/12/-.	11 0 0	11 0 0	11 0 0	11 0 0
17. Making trenches 3 to 4 feet apart (according to the variety of cane to be planted) in November with the ridging plough, one pair of bullocks and two men for two days.	2 8 0	2 8 0	2 8 0	2 8 0

Operations	Cost under bare- fallow system (**bahan**)	Cost under green-fallow system (**Sanchur**)	Cost under **Kharik** system (afer harvesting **Urd** crop)	Cost under **Kharik** system (after harvesting gram crop)
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
18. Widening and deepening trenches with the **Nagar** plough, 2 pairs of bullocks and 3 men for 2 days.	4 8 0	4 8 0	4 8 0	4 8 0
19. Applying cattle manure 150 standard maunds in trenches..	Nil	16 4 0	Nil	Nil
20. Mixing up manure in trenches with the soil by working in them a country plough, one plough for one day.	Nil	1 0 0	Nil	Nil
21. Watering the trenches to moisten the soil. One **charas** (bucket) and one extra labourer for guiding water for four days.	Nil	5 0 0	Nil	Nil
22. Running a country plough in the trenches for incorporating the manure with the soil	Nil	1 0 0	Nil	Nil
23. Cutting top sets for seed and keeping them in the **bijgara** (store-pit)	2 0 0	2 0 0	2 0 0	2 0 0
24. Cost of top sets for seed.	15 0 0	15 0 0	15 0 0	15 0 0
25. Occasional watering to the **Bijgara**	1 0 0	1 0 0	1 0 0	1 0 0

Operations	Cost under bare-fallow system (**bahan**)			Cost under green-fallow system (**Sanchur**)			Cost under **Kharik** system after harvesting **Urd** crop)			Cost under **Kharik** system (after harvesting gram crop)		
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
26. Planting the sets in trenches, 12 labourers for one day.	3	0	0	3	0	0	3	0	0	3	0	0
27. Watering the trenches after ploughing ..	5	0	0	5	0	0	5	0	0	5	0	0
28. Hoeing the soil in trenches with **kudalis,** 10 labourers for one day	2	8	0	2	8	0	2	8	0	2	8	0
29. Six subsequent waterings upto the advent of rains. 1 in March Rs. 5/- 1 in April Rs. 5/- 4 in May Rs. 30/-	40	0	0	40	0	0	40	0	0	40	0	0
30. Six hoeings with **kudalis,** one after each watering	15	0	0	15	0	0	15	0	0	15	0	0
31. Filling in blanks with sprouted sets from the **Bijgara** where necessary	2	0	0	2	0	0	2	0	0	2	0	0
32. Earthing up before rains, 20 labourers for one day	5	0	0	5	0	0	5	0	0	5	0	0
33. Earthing up in August, 30 labourers for one day	7	8	0	7	8	0	7	8	0	7	8	0
34. Tying up of canes, 10 labourers for one day	2	8	0	2	8	0	2	8	0	2	8	0

Operations	Cost under bare-fallow system (**bahan**)			Cost under green-fallow system (**Sanchur**)			Cost under **Kharik** system (after harvesting **Urd** crop)			Cost under **Kharik** system (after harvesting gram crop)		
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
35. Watering in October	5	0	0	5	0	0	5	0	0	5	0	0
36. Night-watching, from April to June, 1 man Rs. 6/- From July to January, 2 men Rs. 28.	34	0	0	34	0	0	34	0	0	34	0	0
37. Carting canes to the crushing-yard ..	10	0	0	10	0	0	10	0	0	10	0	0
38. Fencing with poles and thorny bushes. ..	25	0	0	25	0	0	25	0	0	25	0	0
39. Supervision. ..	15	0	0	15	0	0	15	0	0	15	0	0
40. Land rent for two years in the case of fallow system and for one year in the cases of **Kharik** system ..	20	0	0	20	0	0	10	0	0	10	0	0
Total	302	14	0	274	9	0	256	12	0	256	12	0

It will be seen that the total cost of cultivation of superior varieties under the improved methods varied from Rs. 256/12 to Rs. 302/14/- per acre against Rs. 245 per Bhopal **Bigha** equivalent to Rs. 350 per acre, when the thin local varieties are grown under the existing indigenous system. Against Rs. 350/- however should be set off Rs. 43/- the price of garlic and onion usually grown in the field. Therefore the net cost of cane cultivation as practised by the local cultivator should be regarded as Rs. 307/- per acre.

The average outturn of superior medium canes under the improved **bahan** system in an average season should, if the foregoing instructions are faithfully carried out, amount to not less

than 850 standard maunds, or nearly 31 tons, this figure being based on the results of local experience with intensive cultivation. Reliable figures of outturn under the **Kharik** and the green-fallow systems are not available. Under the indigenous irrigated system, the actual figures obtained by crop cutting experiments, in case of the three main varieties grown in the Bhopal State, have been as follows :—

Variety	Weight of cane yield per acre in standard maunds.
Munhtora.	326
Mandkia.	348
Bhelsai.	376
Average	350

The net result of these investigations therefore is as shown in the following table:—

System	Average cost of cultivation per acre.	Average outturn of cane in standard maunds.	Cost of production of cane per maund
	Rs. As. P.		
Indigenous	307 0 0	350	14.04 annas
Improved **banan**	302 14 0	850	5.7 annas.
Difference	Rs. 4 2 0 (decrease in cost)	500 Maunds (increase in outturn).	8.34 annas (decrease in cost).
Percentage	1.34%	142.8%	59.5%

It will be clear from the above figures that by replacement of the indigenous thin varieties by the improved Java and Coimbatore seedling canes and adopting the improved agricultural methods suggested, it will not be outside the range of possibilities to reduce the present cost of cultivation by 1.34 per cent and yet obtain a produce about 143 per cent higher, bringing down the cost of production from 14.04 annas to 5.7 annas per maund of cane. The Indian Sugar Committee's estimate (Vide para. 282 of their

report) of the cost to the cultivator of raising the thin indigenous canes of Upper India has been between 5 and 6 annas a maund with which the figure arrived at in the Bhopal experiments compares very favourably. It may be noted that the cost of production per maund of cane varies from 4.63 to 4.75 annas per maund in Java while it amounts to 5.73 annas at Shahjahanpur and 5.7 annas at Manjri (vide page 27 of the Indian Sugar Committee's Report).

If therefore cane cultivation on improved lines is adopted and extended year after year, there is apparently no reason why cane of the first and second growth should not be available in Bhopal for factory purposes at 6½ annas per maund delivered at the factory.

The present excessive cost of production in Bhopal accounts for the high rates of **gur** in the local market.

B. The Ratoon Crop.

Below is given a detail of the cost per acre of growing a ratoon crop under the improved system:—

		Rs.	A.	P.
1.	Burning the stubbles after harvesting the plant crop and watering after burning the stubbles. One **charas** (leather bucket) and one man for guiding water, 6 days	7	8	0
2.	Stirring up spaces between the rows of canes with the country plough	1	0	0
3.	Filling in blanks with sprouted sets from the **Bijgara.**	2	0	0
4.	Second watering	5	0	0
5.	Two hoeings, after second watering, with the **Kudali** or **Khurpi.**	5	0	0
6.	Two subsequent waterings during the hot weather	15	0	0
7.	Two hoeings with the **Kudali,** one after each watering	5	0	0
8.	Application of cattle manure, 150 standard maunds before the last watering	16	4	0
9.	Earthing up just before rains, 20 men for one day	5	0	0
10.	Earthing up in August, 30 men for one day ..	7	8	0
11.	Tying of canes	2	8	0

		Rs.	A.	P.
12.	One watering after the rains, in October ..	5	0	0
13.	Night-watchings	34	0	0
14.	Supervision	15	0	0
15.	Repairs of fencing	5	0	0
16.	Cartage of cane to the crushing yard	10	0	0
17.	Land rent for one year	10	0	0
	Total Rs.	150	12	0

As stated before, the outturn of a ratoon crop of any of the imported seedlings except Co 221 which yielded 756 standard maunds of cane has not yet been satisfactorily determined. Cultivators believe that the yield from a ratoon crop of the indigenous **Dhaul** or **Bhelsai** is about 2/3 rds of that of a plant crop. Ratoon crops of seedling canes are in no way inferior to those of the local varieties. Assuming the average outturn of the former on that basis to be 566 standard maunds and the total cost to be Rs. 150/- the cost of production per standard maund of ratoon cane would hardly exceed 4.24 annas.

The yield of improved or superior canes.

It has not been possible to carry out any proper manurial experiments to determine the effect of the various manures on the quantity of the outturn. In the first place soil of homogeneous quality, so necessary for inauguration of such trials, was not available at any of the experimental stations. In the second place the organic manure which it was possible to secure was of unknown composition and by no means rich. Besides it was applied sparingly and only in the trenches, the land having in some cases, been green-manured by ploughing in a hemp crop at the usual time in the rainy season. The supply of water for irrigation during the hot weather (except at Sewanian where a power pumping plant was working) had to be obtained by leather buckets worked by bullocks, from unusually deep wells, with the result that the crops had to tide over the trying heat of the summer months with little more than the minimum quantity of water necessary to keep them going till the monsoon rain set in. It was crops grown under such conditions that were harvested to ascertain the yield from different varieties. The result of the crop-cutting experiments carried out are embodied in the annexed **statement.**

Statement showing acreage outturn of different varieties of sugarcane :—

Variety of cane.	Whether plant crop or ratoon.	Date of harvesting	Farm in which crop was grown	Plot No.	Yield of cane per acre In standard maunds.	Yield of cane per acre In tons.	Remarks.
P. O. J. 33	Plant	5-3-24	Sewanian	Not available.	591.97	21.72	Weight of green tops is not included in any of the outturns enumerated in this statement. It varies from 1/5th to 1/6th of the weight of cane after removal of the tops which are usually utilised for planting.
S. 48	,,	5-3-24	,,		674.45	24.75	
A. 42	,,	6-3-24	,,	,,	560.00	20.55	
S. 39	,,	8-3-24	,,	,,	588.19	21.58	
Co. 214	,,	8-3-24	,,	,,	425.3	15.60	
Co. 221	,,	9-3-24	,,	,,	661.5	24.27	
S. 48	,,	8-1-25	Nuzhat Afza	5	484.79	17.79	
Co. 214	,,	9-1-25	,,	12	373.11	13.69	
Co. 221	,,	11-1-25	,,	12	508.39	18.65	
P. O. J. 33	,,	12-1-25	,,	16	416.05	15.27	
Yuba	,,	14-1-25	,,	12	522.07	19.15	
Yuba	,,	19-1-25	,,	5	622.03	22.83	
S. 48	,,	14-1-25	,,	5	482.33	17.7	
S. 48	,,	20-2-25	,,	6	562.62	20.65	
S. 48	,,	13-2-26	Nabi Bagh		619.0	22.71	
S. 48	,,	5-2-26	,,		500.0	18.35	
S. 48	,,	7-2-26	,,		570.0	20.92	

Statement showing acreage outturn of different varieties of sugarcane.

Variety of cane.	Whether plant crop or ratoon.	Date of harvesting	Farm in which crop was grown	Plot No.	Yield of cane per acre		Remarks.
					In standard maunds.	In tons.	
P. O. J. 33	Plant	8-1-27	Nuzhat Afza	9	656	24.1	Crop in plot no. 9 was attacked by red rot.
,,	,,	22-1-27	,,	,,	659	24.2	
,,	,,	23-1-27	,,	,,	670	24.6	
,,	,,	20-1-27	,,	35	718	26.4	
Co.213	,,	9-1-27	,,	23	573.6	21.0	
,,	,,	20-1-27	,,	,,	623	22.9	
,,	,,	21-1-27	,,	,,	700.5	25.7	
,,	,,	10-2-27	,,	,,	573.27	21.0	
S.48	,,	7-1-27	,,	26	825.6	30.3	Crop of S.48 in plot No. 26 was treated liberally with ammonium sulphate in addition to cattle manure
,,	,,	24-1-27	,,	,,	754	27.7	
,,	,,	17-2-27	,,	,,	951	34.9	
Co.221	,,	8-1-27	,,	23	779.5	28.6	
,,	,,	4-2-27	,,	,,	507.5	18.6	
,,	,,	18-2-27	,,	,,	768	28.2	
,,	Ratoon	10-1-27	,,	,,	756.7	27.8	
,,	,,	19-2-27	,,	,,	756.66	27.8	
Manjav	Plant	9-1-27	,,	15	386.3	14.2	
,,	,,	7-1-27	,,	23	363.6	13.3	
Madan Mahal (247 B.)	,,	20-1-27	,,	35	854.7	31.4	
Local Paunda (white)	,,	7-1-27	,,	23	832.6	30.6	Crop of Local Paunda in plot No.23 was attacked by red rot.
Co.214	,,	24-1-27	,,	,,	459	16.8	
Co.210	,,	14-2-27	,,	,,	784	28.8	
Co.205	,,	15-2-27	,,	,,	642.7	23.6	
Waxy Red	,,	16-2-27	,,	,,	516	18.9	

Statement showing the yield of **rab** and **gur** obtained from different varieties of cane in the crop-cutting experiments carried out at the Bhopal Farms.

Variety of cane.	Whether plant crop or ratoon.	Date of harvesting	Farm in which crop was grown	Field No.	Yield per acre		Remarks.
					First Massecuite or **rab** in Std. Mds.	**Gur** in Std. Mds.	
P. O. J. 33	Plant	5-3-24	Sewanian	**1924**	85.0		
S. 48	,,	5-3-24	,,		86.62		
A. 42	,,	6-3-24	,,		60.0		
S. 39	,,	8-3-24	,,		78.65		
Co. 214	,,	8-3-24	,,		60.4		
Co. 221	,,	9-3-24	,,		82.44		
				1925			
S. 48	,,	8-1-25	Nuzhat Afza.	5		56.7	
Co. 214	,,	10-1-25	,,	12		43.4	
Co. 221	,,	12-1-25	,,	12		66.71	
P. O. J. 33	,,	13-1-25	,,	16		63.31	
Yuba (S. 39)	,,	14-1-25	,,	12		55.34	
S. 48	,,	15-1-25	,,	5		67.37	
Yuba (S. 39)	,,	19-2-25	,,	5		72.82	
S. 48	,,	20-2-25	,,	6		80.16	
				1926			
S. 48	,,	13-2-26	Nabi Bagh	6	87.34		
S. 48	,,	5-2-26	,,	6/1	48.6		
S. 48	,,	7-2-26	,,	6/1	72.8		
				1927			
P. O. J. 33	,,	8-1-27	Nuzhat Afza	9	84.2		
P. O. J. 33	,,	20-1-27	,,	9	104.0		
Co. 213	,,	9-1-27	,,	23	77.6		
Co. 213	,,	20-1-27	,,	23	93.8		
Co. 213	,,	21-1-27	,,	23			
Co. 213	,,	10-2-27	,,	23	83.8		
S. 48	,,	9-2-27	,,	35	92.0		

In view of the circumstances described in the foregoing paragraph it must be acknowledged that no scientific value can be attached to or claimed for the results indicated in the above tables. They merely go to show what outturn the practical farmer of Malwa might get with his existing resources, by merely substituting superior varieties for indigenous ones, with some deviation from the current practice in the matter of cultivation. It will be seen that in every case the yield of the imported canes has exceeded and in many cases very considerably the average (12 to 13 tons) obtained with the indigenous canes.

It was noticed that when a crop of S. 48 was heavily manured with Ammonium sulphate in addition to farmyard manure in field no. 26 (Nuzhat Afza), the outturn of cane per acre was the highest but the crop lodged very badly, the sugar content in the juice was markedly low and the **rab, gur** and sugar made from it were all very inferior in quality. Equally undesirable results were obtained when a crop of the local **Dhaul** was very generously treated with organic manure in another farm, and on account of the poverty of the cane in sucrose content the **gur** was made to solidify with difficulty by special lime treatment and rapid boiling of fresh juice. It is thus a matter of great importance to ascertain by repeated trials the quantity of manure which would yield the best results when growing thick and medium canes, specially the new Coimbatore seedlings in the various soils of Malwa.

All that could be ascertained so far is, that under the improved method of cultivation, satisfactory outturns are undoubtedly obtained from uperior varieties by moderate manuring without much irrigations and that the various forms of sugar made from such crops are generally of very good quality.

In the local cane husbandry, the poverty of the juice in general. in the case of the **Dhaul** and **Bhelsani** is attributable to excessive manuring and irrigation usually resorted to by the cultivator when growing indigenous medium canes.

CHAPTER VIII.

Irrigation of Sugarcane under improved method of cultivation.

The question of irrigating cane crop especially of the superior improved varieties is so important with reference to the Malwa conditions, as to make it desirable that some space should be devoted separately to a discussion of the subject. As has been stated already, the number of waterings in the local practice is, not uncommonly, as high as 30 between the time of planting and that of the harvest, if not till the commencement of the monsoon rains, even when the cultivation of the crop is confined to thin kinds such as **Munhtora** and **Mandkia.** It is indeed the labour and expenditure involved in this item of cultural work that deter many a cultivator from extending the cultivation of the crop for production of sugar, as distinguished from raising thick soft canes as a garden crop to be sold for chewing purposes. In the latter case the financial gain is usually large enough to pay for the heavy cost of irrigation and still leave a good margin of profit. But the consumption of the **Paunda** canes for chewing is so small, and the demand for them in the market so limited, that the question of their cultivation is hardly deserving of serious attention when the same is considered from the commercial or economic point of view. It is in increased cultivation of cane, at the least possible expenditure, for the manufacture of the commercial product sugar, (may be raw, white or refined) that the mutual interest of the agriculturist and the manufacturer mainly lies. Thus while the thin indigenous varieties must be replaced by the superior imported ones from Coimbatore or other cane-growing Government Farms, and the method of cultivation must be materially altered, it is also necessary that the cost of watering the crop and the labour involved in the operation should be considerably reduced, and it is with this aspect of the matter that the following observations are concerned :—

In the existing practice the principal appliance for lifting water from wells and streams is the self-emptying bucket known as the **Sundia pur,** consisting of a leather bag to the bottom of which a long leather tube is attached, the upper corners of the bag being fastened to an iron ring by leather thongs or more commonly to an oblong wooden frame-work. A strong rope is tied to the iron bar fixed to the ring or to the wooden frame-work at the top of the bag, and a thinner one to the lower end of the tube. The bag is pulled up by a pair of oxen by means of the former rope which passes over a pulley fixed directly above the receiving trough, the thinner rope preventing obstruction to the flow of water through the tube.

The lift is so well known in Malwa as hardly to need a detailed description. In this arrangement, which is used for raising water from wells as well as from streams (**Orhis**), the bullocks usually walk down an inclined plane but are not unyoked at the foot of the plane and have to walk backwards (on their hind legs) up the slope. This manner of walking being unnatural, the cattle have to be trained in performing the uphill task. The hardship caused to the bullocks in doing this duty is unduly severe, involving great waste of energy and time. Under this system the desired rapidity in the execution of irrigation work is an impossibility, and for obvious reasons it is particularly unsuitable for deep wells or where large areas have to be commanded. Here lies the main reason which stands in the way of increased production in Malwa of a very valuable crop, and accounts for the existing defects in the local cultural practices and for the low yields. The deep tilth required for successful growth of the crop has to be avoided because that would mean demand for a larger volume of water. The crop has for the same reason, to be planted on flat ground instead of in trenches, and the hoeing of the crop which should follow each watering has to be dispensed with. The plants are not earthed up because the trenches which will thereby come into existance would hold water in larger quantities. A smaller area will then be served during the working day and the cost of the operation will thus increase. Part of the crop at the farther end of the field will not get water when most wanted. Under this system the water merely flows on practically compact ground moistening the surface soil only; hence the need for such frequent waterings as the local cultivator is compelled to apply.

Irrigation from wells is also carried out, though to a smaller extent, by means of the Persian wheel or **rahat** which consists of a large wooden drum over which passes an endless rope-ladder with small earthen buckets attached to it at distances of one or two feet. The drum is made to revolve by means of bullock power imparted to it through the medium of a wooden toothed-wheel gearing of primitive construction worked continually by a wooden lever to which the cattle, walking round and round on a raised platform of mud, are yoked. Sometimes all parts of the **rahat** other than the lever are made of iron. The rope-ladder with the buckets goes into the well (or tank fed through a channel from a running stream or an embanked reservoir) below the surface water and brings it up in the buckets to the discharging level where they empty themselves automatically into a trough. From there the water flows into the field through the main channel.

On account of its flexible nature the Persian wheel arrangement may be adapted for any depth of well. It causes no undue strain or inconvenience to the working cattle and is workable by

bullocks and the cheaper male buffaloes alike. Under this system more water is lifted in a given time by one pair of animals than with the self-emptying bucket and a more continuous flow of it into the field is secured. For improved cultivation it is therefore decidedly preferable to the other system where available. But the **rahat** demands an initial outlay varying from Rs. 150/- to Rs. 200/- or more according as it is made of wood or of iron, which many cultivators would perhaps be unable or unwilling at this stage to invest. Therefore for those who must work with the well-bucket and wish to follow the improved method of cultivtion indicated before, it would be well to adopt the "**killi**" system in general use in the Meerut Division of the U. P. and further west in the Punjab, which has been tried very successfully at the Bhopal Farms, where the author has carried out his experimental cultivation of the superior varieties of cane.

In this case the leather bag which is usually larger than the local self-emptying bucket and has no tube attached to its bottom is ordinarily made of a whole bullock hide (locally tanned) with its corners cut off and tied by leather tongs to an iron ring about 17" in diameter, the depth of the bucket varying from 2'-2" to 2'-4" It holds up to 45 gallons of water. The bag is drawn by means of a rope which is fastened to the bucket at one end and to the yoke on the other, by a pair of bullocks which walk down an inclined plane. As soon as the bucket has reached the top of the well, the labourer stationed there gives a signal to the driver who disengages the rope from the yoke by detaching the wooden peg with which the rope was attached to the yoke. Meanwhile the attendant standing near the discharging trough empties the bucket and throws it into the well into which it descends, pulling the rope by its own weight. By the time it is filled up with water, the bullocks set free at the lower end of the slope, walk up the plane without a load to be re-yoked for drawing the bucket upwards. This operation is continued throughout the working period and water carried to the field through the channel connecting the well with it. In the ideal form of the system, each bucket is worked with two pairs of bullocks, one relieving the other alternately, and usually two buckets are worked together, one coming up to the top of the well while the other goes down. Four pairs of oxen are thus wanted to work a good well, if the best results are aimed at. The supply of water obtained by this method is usually sufficient to meet the actual requirements of improved cultivation, the essential needs of which are a good depth of loose soil in the trenches prepared after deep tillage, and the loosening of the same by hoeings after each watering, both features rendering it imperative that water should be available in abundance when the crop is being irrigated. These requirements are not fully satisfied by the self-emptying bucket system, in which the only saving of cost

lies in the wages of the one labourer who attends to the bucket at the discharging trough, but the great disadvantages of the system are slow work and inadequate supply of water.

Although the Bhopal soil is remarkably suitable for the growth of San-hemp (Hibiscus Cannabinus) and the Sanai (Crotalaria Juncea) both of which yield excellent fibre for rope making, it is somewhat surprising to find that ropes so essential for irrigation work, are not manufactured locally, the reason being that, the demand for ropes is not brisk owing to the apathy of the agriculturists towards intensive cultivation. The few cultivators that grow irrigated crops, generally employ ropes made with the cocoanut fibre and imported from Bombay. These are not sufficiently durable besides being expensive. A rope of this kind about 80 feet in length and 1¼ inches in thickness costs about Rs. 10/- and while it may answer the requirements of the self-emptying bucket, it goes into pieces after about a fortnight's use in the **Killi** system and is therefore of little use for the latter. In the absence of **san** or **sanai** ropes (the **bariyat** and **nahan** of the U. P.) it is consequently recommended that under the improved method of cultivation an iron flexible wire rope of British manufacture should be used. Such a rope ⅜" in. thickness and of the above length would cost about Rs. 13 delivered in Bhopal and would last for about a year. The **Killi** system cannot be worked with any chance of success without it in Malwa. The cultivator would be well advised to grow **san** on the borders of his cane field which would serve as a fencing and would also yield fibre with which he could make his own ropes.

It has not been possible to obtain comparative figures of working the various systems mentioned above side by side and under similar conditions, to enable the reader to form a definite opinion regarding their relative merits with reference to the area irrigated and the cost incurred in each case. But on the basis of practical experience gained and careful observations made in the matter of irrigating cane, it might safely be said that while the local cultivator could within the season manage an area of one **bigha** (7/10th of an acre) to 1½ **bighas** (or a little over 1 acre) of cane, employing one pair of bullocks and a self emptying bucket on a well the depth of which varied from 20 to 30 feet when working under the indigenous system of planting cane on flat ground, and dispensing with the hoeings, it is certain that he could not properly deal with even 2/3rds of the same area if the improved trench system of growing cane were adopted. On the other hand a crop 2½ to 3 acres grown under the improved method could be conveniently controlled by using the **Killi** system with two buckets, each worked by a single pair, on a well of the above depth, and one of 4 acres if each bucket were worked by two pairs of oxen employed alternately, provided the water supply in the well was enough to work

PHOTO No. 6,

A SMALL PUMPING PLANT USED FOR IRRIGATION AT HER HIGHNESS' FARM AT INTKHERI, BHOPAL.

it all day. It is highly doubtful if for the requirements of intensive cultivation by the improved method, the self-emptying bucket would be of any use at all, when the depth of the well ranged from 50 to 75 feet, as it does during the hottest months of the year in certain parts of the Bhopal territory. But in such parts the **killi** system has been found to be quite capable of coping efficiently with an area of 2 acres during the season, if worked with two buckets, each drawn by a single pair and of 3 acres if by two pairs used alternately.

Use of power machinery for lifting water is far more economical than any of the methods discussed above, but wells suited to the employment of such machinery do not exist at present; those available generally dry up after 4 to 8 hours working in the hot months of May and June, making the question of improving the water supply of wells a separate problem of considerable importance for local agriculture. There are however tanks, streams and rivulets which can be most profitably utilised for irrigation by power-pumping. Rain water can be retained in reservoirs by making **bands** (embankments) in **nalas** which run only during part of the year. Ordinarily the water level in the existing streams is within a depth of 12 to 18 feet from the surface ground and the adjoining areas are highly fertile. It is in lands irrigable from these sources that the best possibilities of cane production on a large scale principally lie at present.

Two enterprising farmers of Bhopal have recently set up locally made double chain pumps worked by hydraulic power created by laying down suitable **bands** and diverting the course of the **Patra naddi,** a toothed-wheel gearing and sluice gate arrangement forming prominent features of the plant. Water can be let in by opening the sluice gate to set the pumping plant in motion and lift the water, or the working stopped by closing the gate. This is by far the most economical method of irrigation from perennial streams and where possible, the admirable contrivance just referred to should be adopted, as the amount of water raised is enough to serve very large areas without much attention to the machinery or the need for replacement of parts. The plant, however, is not portable and would be a useless installation for streams which do not run with sufficient force to produce the power needed.

The author can confidently recommend for general use along the banks of streams and tanks a 4 B. H. P. oil engine mounted on a strong steel girder frame and wheels, combined with 2½ inches diameter centrifugal pump. Such a portable pumping-plant which costs about Rs. 2,500/- at site has been tried in Bhopal with remarkable success and found to be capable of serving an area of 20

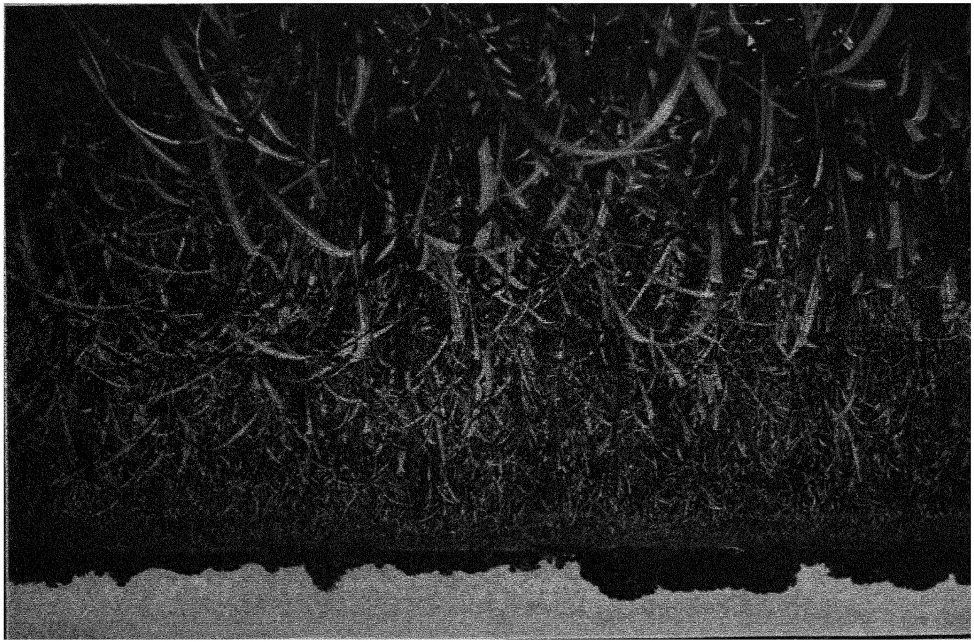
acres of cane adequately. The cost of working it does not exceed Rs. 7/- per day including depreciation. Roughly the total cost incurred during the irrigation season of 5 months amounts to about Rs. 1,100/- or Rs. 55/- per acre of cane which is about 40 per cent of the cost of irrigation by the local well-bucket system. Part of a crop grown with irrigation under this system in the season 1926-27 is illustrated in the picture on the opposite page, the photo having been taken in June 1927 before the advent of the monsoon. If a larger plant is employed, as will be necessary for larger areas, the cost of irrigation will be reduced in proportion.

With regard to the lead of water from the discharging level to the fields, the heavy loss caused by percolation into the absorbent soil of Malwa is a serious drawback, which baffles the efforts of the cultivators in stopping the leakage from mud channels raised on the ground. After making several experiments to overcome this difficulty, it was found that a fairly good water-course could be made by placing trunks of palm and timber trees in a parallel position, one over the other until the requisite height was attained, and then filling up the intervening space with earth and ramming it down as hard as possible. Percolation is thus minimised and the growth of grass on either side of the channel gradually makes the mud structure sufficiently compact.

Whatever system of lifting water may be resorted to, it is important that the cane field should be so prepared before planting as to derive the full benefit of irrigation with the minimum application of water. In the first place it will be necessary to make the field as level as possible by the use of the **patela** and the **karaha,** both commonly used in the cane husbandry of the United Provinces. If the field cannot be levelled fully through the agency of these implements, the only alternative will be to dig the earth by the spade from the higher parts of the field and remove it to the lower portions in order to raise their level. In Malwa, fields are often very uneven and in such cases the observer will at once see that the cane crop on the higher levels usually displays better vegetative growth than on the lower ones. In depressions the growth is generally poor, even before rains, while during the rains waterlogging, which is often unavoidable, causes positive harm.

There should if possible be no trees in, or adjacent to, the cane field. The crop never grows normally in the immediate neighbourhood of trees, or even of bushy hedges such as the **Menhdi** (Lawsonia Alba) and the cause is popularly believed to be the shade (**"chhaun" or "ochhaun"**) though the real reason of the failure is the strong root-system of the trees which absorbs the soil moisture and available plant food, more vigorously than the young roots of the cane, thus depriving the latter of the requisite supply of

Photo No. 7.



A young crop of S.48 four months old irrigated from a Stream by a Pumping Plant. June 1927.

nourishment. If trees cannot be avoided, the mischief will be minimised by digging a drain of requisite length about three feet wide and three or four feet deep between the trees and the field, so as to cut off the radical connection between them. This operation should, in order to be successful, be carried out before the cane is planted. The main channel connecting the field with the source of water supply should then be made as firm and compact as possible in order to prevent undue loss of water by percolation. The field should be divided into suitable irrigation beds (**kiyaris**) by making distributaries (**barahas**) across the field not more than 30 feet apart so that trenches or furrows (**modhs**) bearing the cane sets should receive the irrigation water in 30 feet lengths at a time. The furrows to be irrigated may with advantage be shorter in length. Long furrows are usually uneconomical, because in them the distribution of water is always uneven, the portion nearer the main channel retaining and absorbing more water than that further down and thus growing a better crop than the portion less favoured. If a portion of the field has a distinct slope, so that water flows downwards with undue rapidity, it will be necessary to check it by blocking the passage of water with mud at suitable distances in the furrows, so as to give the plants the opportunity of absorbing their due share of the water. In the black soils of Malwa cracks usually make their appearance within a few days of watering and these deepen and widen as time goes on. If left alone, considerable quantities of water will be lost in them when the next watering is being given and much labour wasted in filling them up by the spade or **kudali.** To prevent that occurrence, the field should be hoed after irrigation as soon as the soil is in a fit condition to admit of that operation, which not only prevents the formation of cracks but also evaporation of moisture and growth of weeds. These processes should be repeated until the middle of May when the hottest part of the season begins and the crop's demand for supply of water becomes frequent and more pressing. This is the most critical stage of the growth and it is now that the practical skill of the agriculturist comes into requisition and finds the best scope for its use. As the reader is aware, the cane field consists of trenches and mounds alternately, the former lower and the latter higher than the original surface ground. The trenches which are generally about 2 feet wide require more water at this stage of the season than can be conveniently supplied with due regard to economy. If the trenches are then filled with earth and the plants earthed up, the space left between the rows of plants, 3 to 4 feet, will be too large to be used economically in Malwa conditions for the passage of water. Therefore in May only a small portion of the earth from either side of the mounds should be cut out to fill up the trenches and no attempt made to earth up the plants. The earth so detached from the mounds should be stored along the rows in such a manner as

to assume the shape of a narrow drain; and it is through this drain that the crop should be watered hereafter till the break of the monsoon; the interspaces being left unirrigated, otherwise a serious deficiency of water will be noticeable and only a poor crop may be the result, or the expenses on irrigation will be excessive. Perhaps Chilo will cause great havoc in parts of the field which fail to get an adequate and timely supply. Soon after the rains have set in, the soil on the mounds should be used for earthing up the young crop and when this has been done the old trenches will assume the appearance of mounds. In short the aim of the cane grower during the most critical part of the irrigation season should be to supply water, just sufficient to keep the crop in a fairly healthy condition without trying to inundate it, and wait till the advent of the monsoon rain, the principal agent of nature which helps rapid growth. The Malwa soil is very difficult to work during the rains. It is therefore important that there should be **no delay** in filling the trenches and earthing up the plants, otherwise there will be the danger of water-logging which is harmful. For the same reason it is necessary to make suitable arrangements for the drainage of superfluous water from the field during the rainy season without allowing manure to be washed away, which is only a matter of properly levelling the land.

In case of ratoon crops, which have, as a rule, to grow on mounds in the improved system of cultivation there is always difficulty in supplying sufficient irrigation water, if the latter has to flow on the interspaces which are about two to three feet wide. In this case narrow drains should be dug on both sides of the mounds along the rows of plants growing on them. The rows should, in view of economy, be watered through these drains, the intervening blank spaces remaining unserved. The roots will thus be kept in fairly good condition during the hot weather and will throw off an abundance of young shoots in the rainy season which will gradually develop into canes of normal height and thickness, if other conditions are favourable.

CHAPTER IX.

Bullock-Power Cane-Crushing Mills.

The old stone mills have now been completely replaced by the iron mills, though a large number of the former still exist in the cane growing tracts of Bhopal merely as relics to recall to the cultivator's mind how his forefathers dealt with their cane harvest in the olden days.

The Nahan three-roller mills, which have gained almost universal approbation from the cane-growers of the United Provinces and the Punjab on account of their efficiency have, not yet attracted the attention of the Bhopal cultivator, though they have attained access to the planters as far away as Mysore. Nor is the 2½ roller Behea mill known in the territory. Speaking generally the cultivator of Bhopal hires his iron mill and the boiling pan for the season from capitalists who stock them and make enormous profits in that business, the charge for the mill being Re. 1/- and for the pan annas 6 per day when hired for short periods. For the season the hire for the mill and the pan varies from Rs. 40/- to 50/-. Two-roller mills which yield a low extraction (about 50 to 55 per cent of juice on the cane) are not uncommon though three-roller mills (also of local construction) giving a higher extraction are largely used, yielding about 60 per cent of juice from the indigenous canes and often somewhat less. The quantity of extractable juice lost on account of inefficiency of the mills is considerable and may be estimated at 25 per cent of the juice contained in the cane.

During the past 6 years, the Department of Agriculture has demonstrated the use of the "Hathi Mill" (a three-roller machine) manufactured by Messrs Burn & Co. of Calcutta, and this has proved an incentive to the local manufacturer to improve his mills which he has done with no small success. During the last two seasons the American Chattanooga three-roller Mill (No. 12) workable by the average sized local cattle has been used and demonstrated and but for the fact that the bed plate and the top cover in this mill have been found to break as a result of the ordinary unavoidable strain the mill is sufficiently good. Two mills of this type were used for the daily work at one of the Bhopal Farms. In both of them the cast iron cover and plate broke down and had to be repaired by putting on a plate of wrought iron and fastening it firmly with bolts and nuts. Then they became serviceable again.

In season 1924-25 Messrs Kirloskar Brothers of Kirloskarvadi, District. Satara, sent out a mill of their manufacture named "Kisan Mill" which has been worked quite easily by a pair of average

Malwa Bullocks. All these types were tested side by side with the mills of local manufacture. A careful trial to compare the merits of the various mills was held on the 3rd of March 1925, when over-ripe cane of the variety S. 48 was used for crushing, and the results are tabulated in the following statement.

Name of Mill	Time during which the mill was worked	Weight of cane crushed	Weight of juice extracted.	Percentage of juice to cane.	Weight of cane crushed per hour.	Weight of juice extracted per hour.	Remarks.
American Chattanooga No. 12 3-roller	One hour & 46 Minutes.	236 lbs.	160.8 lbs.	68.13	133.5 lbs.	91.00 lbs.	The superiority of the first two mills over the local mills was obvious. If the cane were not over-ripe, the extraction would have been higher. The same bullocks were used by turns to work the various mills.
Burn & Co's Hathi Mill 3-roller.	Do.	229.5 lbs.	154 lbs.	67.10	129.9 lbs.	87.16 lbs.	
Local Mill Type I 3-roller.	Do.	227 lbs.	138.8 lbs.	61.14	128.49 lbs.	78.56 lbs	
Do. type II 3-roller	Do.	239 lbs.	147.75 lbs.	61.82	135.28 lbs.	83.63 lbs.	

When these results became known to an enterprising local manufacturer, he worked hard to improve his mill and brought out several mills of his improved design in 1926 for open competition This was held on the 19th February 1926, the thick soft cane P. O. J. 33 being used for crushing. The results are noted in the subjoined table :—

Name of Mill.	Weight of cane crushed.	Time taken for crushing.	Weight of juice obtained.	Percentage of juice to cane.	Remarks.
Kisan Mill 3-roller.	100 lbs.	19 Minutes.	70.25 lbs.	70.25	In this trial "Kisan" saved much time as compared with Chattanooga, while the extraction from both mills was equally good. The improved local mill gave the same extraction as the Hathi but took more time for crushing. Same bullocks were used by turns to work the different mills.
Chattanooga No. 12 3-roller.	Do.	27 Do.	Do.	70.25	
Burn & Co's Hathi Mill 3-roller.	Do.	27 Do.	70.00 lbs.	70.00	
Local (Haji Musa) 3-roller.	Do.	29 Do.	Do.	70.00	

The Kisan was again compared with Chattanooga, the hard skinned variety S. 48 being used on the 20th March 1926 when the crop was over-ripe. The following results were obtained:—

Name of the Mill.	Weight of cane crushed.	Time taken for crushing.	Weight of juice obtained.	Percentage of juice to cane.	Remarks.
Kisan Mill 3-roller.	100 lbs.	26 Minutes.	64.75	64.75	The cane was over-ripe and hard. The Kisan gained in time but lost in extraction. The same bullocks were used by turns to work the two mills. If the cane were not over-ripe the extraction would have been higher in both cases.
American Chattanooga No. 12	Do.	29 Do.	66.00	66.00	

The net result of these investigations is, that at present there are no mills among the local types which could compare favourably with the superior mills, which are in common use in other parts of India, or are known to be far more efficient, and that the Malwa cultivator is sustaining a considerable loss of juice which can be avoided by introduction of better mills. This question therefore deserves attention from all concerned in the sugar industry, quite apart from that of improving the method of cultivation, or introducing superior varieties of cane.

Messrs Marshall Sons & Co. (India) Limited, Bombay, have lately brought out a strong and well finished 3-roller bullock mill which, on being tested along with other improved makes in use at the Bhopal Farms, gave about 1 to 2 per cent more juice from the cane without causing any extra strain on the bullocks and with some saving of time. This mill has recently been improved upon by the makers, the improved form has not yet been tried in Bhopal, but has been well spoken of by the Deputy Director of Agriculture Jubbulpore C.P., who has thoroughly tested the new mill.

CHAPTER X.

A. Manufacture of gur.

The greater part of the Indian cane crop is usually converted into what is known as **gur, gul or** jaggery, except in parts of Rohelkhand and Meerut Divisions of the United Provinces where it is customary to use an appreciable portion of the crop for the manufacture of **rab** which in turn yields the white sugar known as **Khand.**

Gur is a compost of sugar crystals and molasses, prepared by boiling cane juice with or without clarification and concentrating it to the solidifying point when it is cooled and made into cakes of varying sizes and shapes. **Rab** is the product obtained by not carrying the boiling so far. It is potted in order to give the cane sugar naturally present in the juice a chance to crystallise freely. As has been recognised by the Indian Sugar Committee (see para 274 of their Report) "for many reasons, but mainly owing to the small and scattered plots on which cane is grown in India **gur** is always made in small quantities and **its manufacture is a cottage industry**." There is not the slightest doubt that even with the expected gradual introduction and popularisation of the much-desired power plant for extraction of the juice in the more or less remote future, the manufacture of **gur** will remain an important agricultural industry in India, so long as **gur** occupies the prominent place it has hitherto enjoyed as a favourite article of food in both the rural and the urban population. Researches in Bhopal have therefore been directed in the first instance mainly towards such improvements as are within easy reach of the cultivator, without making any radical changes in his existing methods of manufacture and the whole question has been studied in a practical manner from the stand-point of the cultivator dealing with a cottage industry.

The indigenous system of boiling **gur** in Malwa is probably the least judicious of all practised in India. The boiling-pan is made of sheet iron much thinner than the requirements of successful **gur**-boiling demand. The bottom is flat and the round wall slanting towards the bottom. The furnace is a very deep excavation, sometimes as much as 6 feet which necessarily demands heavy fuel consumption, and the supply is possible only because fire-wood happens to be cheap and abundant on account of existence of forests in most of the Malwa villages or in their neighbourhood. It is calculated that the existing cane area in the Bhopal territory requires nearly one hundred thousand rupees worth of fire-wood annually to convert the cane outturn into **gur** calculating the

price at the nominal rate of one anna per standard maund, while it is possible to save nearly the whole of this quantity for more useful purposes by merely altering the furnace so as to make it suitable for burning the bagasse and the trash which are at present wasted. The economic loss is thus rather serious.

The pan in the local system receives inadequate heat for long hours and both charring and inversion of sugar therefore form the most prominent features of the boiling process. In every charge part of the sugar gets literally burnt, so that it is not uncommon to see the bottom and the wall surface of the pan covered with thick black incrustations which are difficult to get rid of by scraping. As a result of this disadvantage, the **gur** produced is always dark or brown, while on account of undue inversion which is inevitable, the final product is never hard enough. Indeed the ideas of the Malwa consumers have become permanently associated with softness as one of the characters of the texture of the Central India **gur,** the richer **gur** of Upper India which is harder on account of presence in it of a higher percentage of sucrose being looked upon as a material foreign to the local taste. The Malwa **gur** is apt to deliquesce during the rainy season, unless all due precautions have been taken to prevent it from coming into contact with the moist air.

In the season 1925-26 the vegetative growth of the cane crop in Bhopal and the neighbouring States suffered materially in consequence of early cessation of monsoon rains (in the latter part of August) and failure of the cultivators who hoped for more rain but received none, to help the crops forward with artificial irrigation. As a result, the percentage of sucrose in the canes was abnormally low and of glucose unusually high. Using the old slow method of boiling the juice in the indigenous pans, the skilled boilers of Bhopal found it impossible to make the **gur** solidify. The final product was either a semi-liquid sticky article or, if boiled longer, a tough unsightly material which fetched from Rs. 18/ to 20/ per **Mani** (4.8 Standard Maunds). Assistance was invoked from the officers of the Department of Agriculture, Bhopal, who visited a large number of such places and demonstrated the fact by merely altering the pans and the furnace so as to secure quick boiling and rapid concentration, that not only could **gur** boiled from the same inferior juice be made to solidify, but that the quality and colour of the **gur** were so markedly superior that the prices offered for the material varied from Rs. 51/- to 55/- per **Mani.**

It will be admitted by all that under any well-known indigenous system of boiling in use in Upper India and Central India, it is not possible to produce **gur** of uniform texture, quality and colour throughout the working day. Each lot manufactured differs

from its predecessor or successor in some way, and it is this difficulty that has been overcome by the investigations recently conducted in Bhopal. A system has been developed whereby **gur** of astonishingly light colour, with a sucrose content as high as 82.82 per cent has been produced uniformly in successive boilings during the whole day and throughout the season. Indeed samples of **gur** have been produced from Manjav, A 42, S.48 and even the local **Munhtora** juice, which the people in the trade refused to accept as **gur,** and they insisted on describing the material as a low grade white or pale sugar moulded into cakes. To secure a uniform product of this quality, it is essential that the furnace should be of special construction and the boiling plant should consist of two pans instead of one viz: (a) the clarifier (**nikhar**)**,** which may be hemispherical or flat-bottomed, preferably the latter, and (b) a concentrator (**parchha**)**,** usually with a bowl-shaped bottom but shallow. If the expense of having a brass clarifier can be afforded, the maximum of success is ensured, but it is not essential to have a brass vessel. A pan made of galvanised iron would, for all practical purposes, serve the object in view, or even one made of thick sheet iron, provided that the inner surface of the pan is carefully cleaned every day before use, by rubbing it over with stones, old gunny bag pieces, sand and an inexpensive acid material such as leaves of the tamarind tree and then washing it freely with water to get rid of incrustations, dark patches, rust etc., which make their appearance as a rule. The second pan, the concentrator (**parchha**)**,** should be made of wrought (not sheet) iron with a smooth inner surface free from crevices, which harbour the caramelised sugar, and with a particularly heavy bottom, which never gets over-heated and retains heat longer than if it were made of thin sheet iron. There are blacksmiths in Bareilly and other parts of Rohelkhand whose sole business it is to make and sell such pans. Until the Bhopal artisan learns to produce similar ones, it would be better to import them from Rohelkhand.

In the first place, the prevalent custom of boiling the juice day and night must be deprecated as being detrimental to the objects of successful working. For obvious reasons the cost of working throughout the night is heavy, there being greater chances of charring of the boiling material than during the day; and the night boiling is always slower, causing greater inversion. Besides these serious drawbacks, the manufacturer cannot find the time to cool and clean the iron pan or repair the furnace when necessary, if it is to be worked without break. Undue strain caused by continuous work for a prolonged period to the cultivator and his family, who share the supervision and management with him, gradually lessens their keenness and matters are allowed therefore to take such course as they will. With the best of his

efforts the cultivator can produce only about 2 Bhopal maunds or 2.4 standard maunds of **gur** in 24 hours. It has been determined that a greater outturn than this can be obtained by working a good three-roller mill for about 10 hours and an improved set of boiling pans for about 14 instead of 24 hours, at a smaller cost of labour, while the cultivator can also find time to get undisturbed sleep during the night, and opportunity on rising to clean the vessels properly before resuming the operations, and thus to keep the quality of his **gur** up to the desired standard.

The dimensions of pans for such boiling plants are as follows:–

(a) For a plant to boil the juice ordinarily extracted by a three-roller 8″ diameter bullock-power iron mill worked for about 10 hours daily, yielding 15 to 16 standard maunds of juice. (See Illustration I).

(i) **Clarifier.** This should be a round flat-bottomed vessel provided with a brass-cock.

Diameter 2 feet 3 inches.

Depth. 1 foot 2 inches.

(ii) **Concentrator.**

Diameter 2 feet.

Depth $6\frac{1}{2}$ inches.

If a flat-bottomed clarifier is not available a hemispherical iron pan, 2 feet $7\frac{1}{2}$ inches in diameter and 11 inches deep, or slightly larger vessel, may be used instead, the size of the concentrator remaining the same as recommended in the former set. (See Illustration II.).

(b) For a plant corresponding with the yield of two similar mills working during the day and producing 30 to 32 standard maunds of juice. (See Illustration III.).

(i) **Clarifier.** A round flat-bottomed pan.

Diameter 2 feet 6 inches.

Depth 1 foot 3 inches.

(ii) **Concentrator.**

Diameter 2 feet 9 inches.

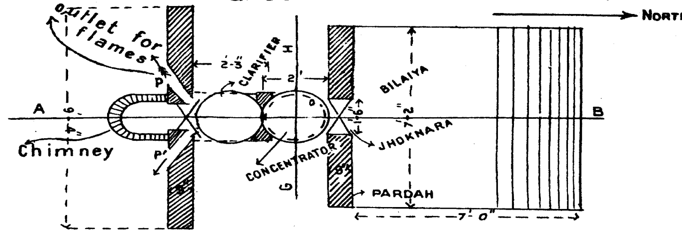
Depth. 7 inches.

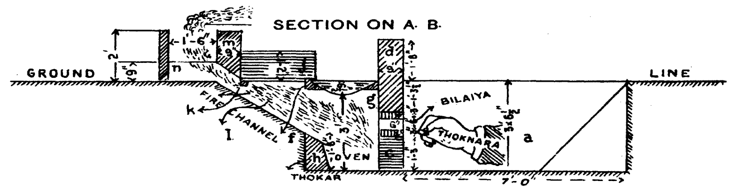
ILLUSTRATION NO. I

IMPROVED GUR AND RAB BOILING PLANT AND FURNACE

GROUND PLAN

Scale 4 Ft.=1INCH

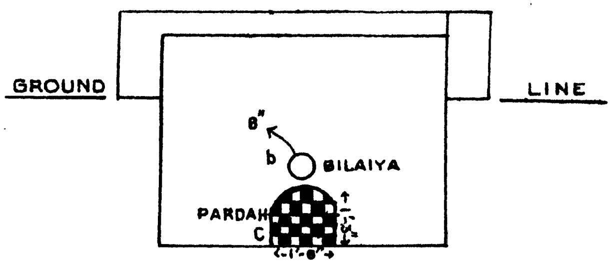




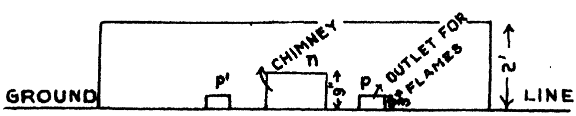
(a) The fuel pit
(b) The bilaiya or the feeding orifice
(c) The pardah or the semicircular arch
(d) Wall 9″ thick
(e) Concentrator
(f) Arch made of sun-baked bricks on which the southern corner of the concentrator rests
(g) Oven on which the concentrator is placed
(h) The slope (thokar) along which the flames proceed higher up.
(j) Clarifier
(k) Arch on which the clarifier rests towards south
(l) The channel along which the current of fire travels
(m) Wall against which the clarifier rests
(n) Dhundu, the main outlet for flames and smoke escaping from channel (1)
(o) Sancha represented by dotted lines denoting the mud plastering (Got) on which the pan is placed.

ILLUSTRATION NO. I (A)

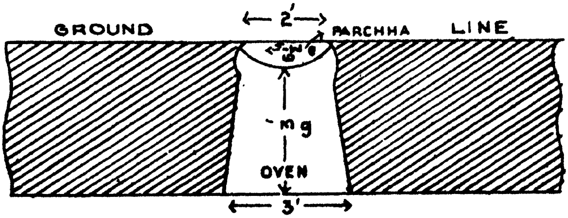
FRONT ELEVATION



BACK ELEVATION



SECTION ON G. H.



The cultivators of Malwa would be well advised to adopt the last mentioned set of pans in view of economy in the cost of production of **gur**. There should be no difficulty in working two mills and boiling the juice yielded by one in half the day and by the other during the remaining half. Such an arrangement would certainly lead to the mutual benefit of any two cultivators who may agree to it between themselves. In such a case each cultivator's cane shall be crushed in both the mills and the juice boiled by turns in the same set, causing substantial saving in labour and fuel. Where more than two cultivators can club together three or more mills may be worked in the same crushing yard and one or more vessels of the shape and size of the clarifier may be set up behind the clarifier to receive and boil the extra quantity of juice. Such an arrangement of pans though not illustrated here has been successfully worked in Bhopal.

The furnace for the improved sets of pans has been designed on the principle of the Rohelkhand **bel**, in order to ensure complete combustion of the fuel and judicious distribution of the heat. That principle will be discussed in full detail later in chapter XI. dealing with the Rohelkhand **bel** and the new **rab** boiling apparatus recently elaborated in Bhopal. Reference is invited to illustration No. I which gives a vertical section of the smallest set of improved design installed on a furnace, and a ground plan of the latter. Illustration No. I (a) gives minor details which are self-explanatory. Speaking briefly the furnace begins with an excavation (a) about 7 feet long, 7 feet 2 inches wide and 3 feet 6½ inches deep with a slope at the northern end. Dry fuel is stored in this pit from time to time to be used by the feeder who sits close by, on the floor of the pit. At the southern end of the pit there is a wall (d) about 9 inches thick made of sun-dried bricks. At the bottom of the wall there is a semi-circular arch (c) called **pardah** which is 1 foot 3 inches in height and 1 foot 6 inches wide at the base. About three inches above the arch there is a circular orifice (b) known as **bilaiya**, 6 inches in diameter which must always face the north. Adjacent to the wall (d) the main oven (g) is dug up, being a round conical excavation having a diameter of 3 feet at the bottom and one of 2 feet at the top with a slight curve towards the end of the top height of the oven, as shown in Illustration I (a). The concentrator (e) is made to rest on an arch against the wall (d) at the northern end and on the arch (f) towards south. In the oven (g) at a height of about 1 foot 6 inches from the bottom towards south, there is a slope called **thokar** (h) at the top of which begins a channel (l) 1 foot 6 inches wide connecting the oven (g) with the outlet (n). Along this channel travel the flames escaping southward from the oven. Vessel (j) is the clarifier resting over the arch (f) at one end and arch (k) at the other, the distance between the two arches being about 1 foot 11 inches. Adjacent to

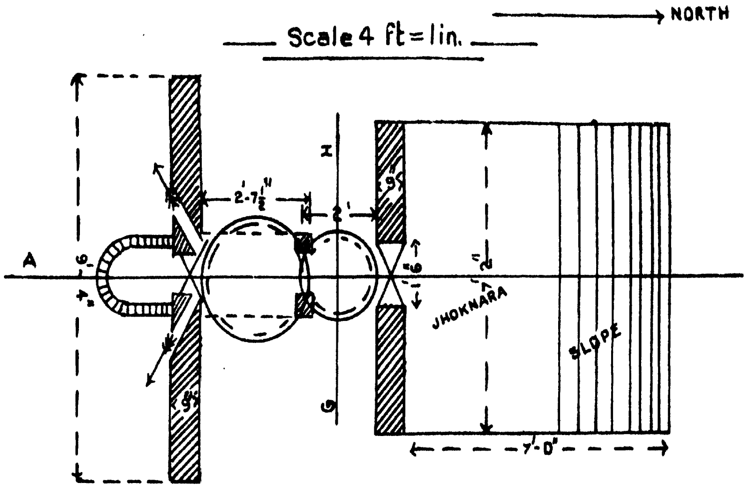
arch (k) towards south there is another wall (m) similar to wall (d). The heights of the two walls may vary according to convenience but wall (m) must be high enough to prevent soot from the smoke and flakes from the **dhundhu** (n) coming into the juice or clarified liquor present in the clarifier (j). At the top of oven (g) there is a round mud-plastering (o) known as **sancha** or **got** (shown in the ground plan with dotted lines,) over which the concentrator (e) is firmly fixed. When this has been done the boiler man enters the oven through the pardah arch (c) and plasters the concentrator round with mud from within the oven, so as to close any small crevices that may be there between the **sancha** and the pan and thus effectively prevent all possibilities of smoke or flame coming out at the top of the concentrator. This procedure should, as a precaution, be adopted with regularity every morning when the oven is not hot. If neglected, the plastering within the oven is apt to give way. In that case the part of the pan whence the plaster has dropped down, will get over-heated and charring of sugar will at once begin. When this happens, it is impossible to control the charring except by stopping all work and waiting till the furnace is sufficiently cool to admit the plastering being done from within the oven. The oven under the clarifier (j) should receive exactly the same treatment of plastering every morning before work is begun. The outlet (n) should not be raised high to look like a chimney as it has occasionally to be closed temporarily with a brick or bricks to regulate the heat received by the two pans. When, in course of the feeding, it is found that the concentrator is receiving less heat than is necessary for rapid concentration the outlet (n) should be wholly or partially closed according to the amount of heat needed. On the other hand, if at any time it is noticed that the clarifier is not getting enough heat to make quick and efficient defecation of the juice possible, the brick or bricks should be removed, when it will be found that good clarification is done within the desired space of time. The smaller outlets (p and p')—vide ground plan—are meant for the same purpose, as also for preventing undue waste of the heat generated in the main oven and should be utilised similarly as need arises.

Illustration II, represents an arrangement intended merely for the guidance of those who do not possess a flat-bottomed clarifier but still desire to make better **gur** at a reduced cost and in a shorter time. Although a certain amount of charring in the clarifier is unavoidable in this arrangement, and it cannot therefore be recommended, yet because bowl-shaped pans of the size of the clarifier shown in the illustration are easily available in villages being used generally in kitchens and by confectioners, the cultivator would do very much better by using this arrangment in preference to the local system. The construction of the furnace in this case is based on the same lines as indicated in illustration No. 1.

ILLUSTRATION NO. II

IMPROVED GUR AND RAB BOILING FURNACE USING BOWL SHAPED PANS

GROUND PLAN



SECTION ON A. B.

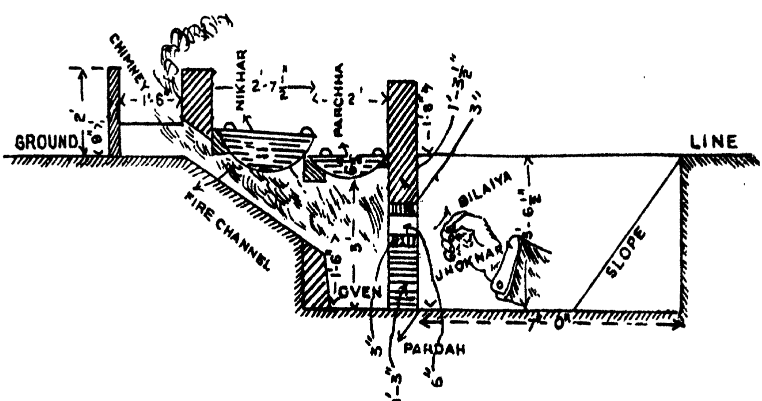
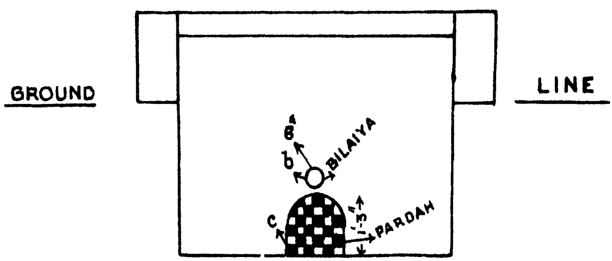
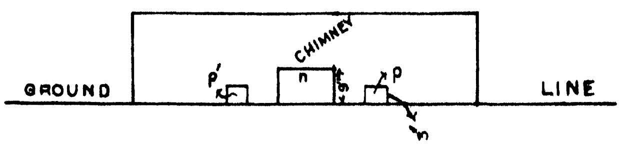


ILLUSTRATION NO. II (A)

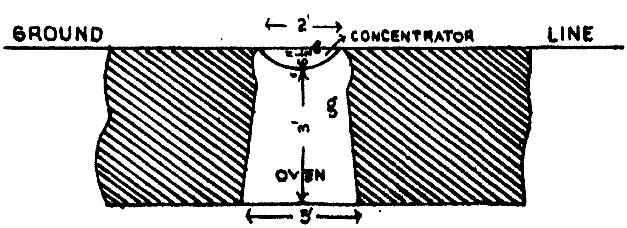
FRONT ELEVATION



BACK ELEVATION



SECTION ON G. H.



These furnaces have been so devised as to be capable of boiling the juice with the use of bagasse alone as fuel, but the bagasse may be mixed with trash or dry stalks of **Gokhru,** or **Panwar** (Cassia Tora) which grow wild in abundance round about cultivators' fields, or with fire-wood or dried **Mahua** (Bassia latifolia) or Mango or **Khankar** (Butea frondosa) leaves, as may be desired. There are two orifices for feeding the furnace as shown in the illustrations, a round small one (**bilaiya**) over the arch (**pardah**) and a semi-circular one at the bottom of the front wall. When bagasse alone is used the arch (**pardah**) is closed temporarily with bricks as shown in illustration No. (Ia) so that draught of air may enter principally through the **bilaiya**. In all other cases the lower arch is used as the feeding point and the smaller round hole (**bilaiya**) is closed with mud. The best control of the heat is secured by using bagasse as fuel, provided it is used quite dry. In that case the combustion is so perfect that there is very little accumulation of ash in the front oven. It cannot be urged too strongly that the boiling should be AS RAPID AS POSSIBLE and this cannot be secured if the fuel is green, wet, or even moist. All fuel used must be absolutely dry, otherwise the boiling will be slow and undue inversion will follow, which means a product of interior quality. Ordinarily the bagasse is the main, if not the only, fuel to be employed, except during the first few days at the commencement of the operations, or when the weather is rainy or cloudy as is sometimes the case during the boiling season. Hence it is important that the bagasse which collects at the foot of the crushing mill, should be removed at suitable intervals, spread in the sun and occasionally turned over with the tined wooden instrument designed specially for the purposes and called **pancha,** Late in the afternoon it should be collected into a heap to avoid being wetted again by the falling dew. The heap should be spread again the next morning, unless it is quite dry. Bagasse contains about 6 to over 8 per cent of cane sugar, a combustible substance, and on that account burns remarkably well, imparting very strong heat to the pans; in fact no other fuel available can approach it in respect of intensity of the heat produced and bagasse is rightly recognised by the boiler of Rohelkhand as the "King of fuels", if properly prepared. Speaking generally the weight of bagasse produced is sufficient to boil the juice from the cane which gave the bagasse if used in conjunction with the trash yielded by the same cane. It is possible that with certain canes like Paunda which yield a very high percentage of juice, or the extraction has been particularly good and the mill refuse too fine or powdery, the quantity of the bagasse may be found inadequate. Should this happen the bagasse must be supplemented with other materials, such as fire-wood of any description. In Bhopal one would first take for this purpose the dry leaves of the **Khajur** tree (Phoenix Sylvestris) which grows wild in abundance, or dried

branches of the **Khankhar or Dhak** plant (Butea Frondosa) both of which materials form splendid fuel. In the new system the fuel consumption would be considerably smaller than in the wasteful method at present prevailing in Malwa.

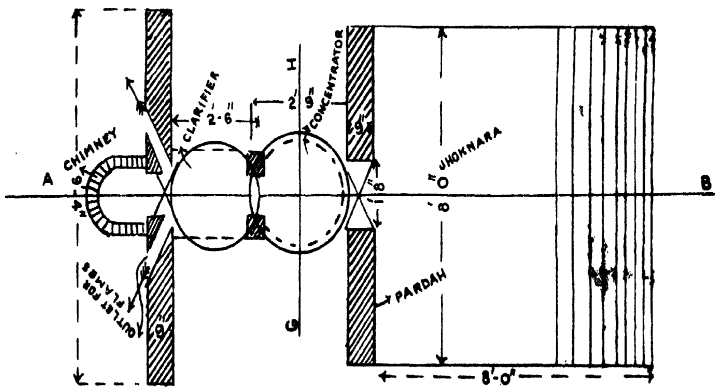
To start the boiling both pans should be charged with as much juice as they are capable of holding conveniently, viz. about 1/2 tinful (20 to 21 lbs) in the concentrator and about 3 tinfuls in the clarifier. Fire then should be lit in the oven under the concentrator and feeding of the furnace continued regularly to maintain an intense fire. The scum will soon begin to rise on the surface of the concentrator and a hissing sound produced as a result of gentle evaporation, and up to this stage the juice in the pan must not be disturbed in any way. As soon as this simmering sound ceases to be perceptible, the vegetable defecant which the boiler man keeps ready should be poured in, not in driblets, but as far as the quantity required can be judged, which is a matter of experience, all at once. The defecant is prepared by pounding in water the green stems of the wild **deola** (Hibiscus Ficulneus), or, failing it, of the cultivated variety (Hibiscus Esculentus) known as Lady's finger, **Ochro** or **Bhindi.** The crushed stems are rubbed between the two hands to yield a mucilaginous liquid, which pours thickly, and of this about one-eighth of a kerosene tinful should be an ample dose for the concentrator and about 1/2 or 3/4 of a tinful for the clarifier. Other defecants, but not such good ones, can be made from the bark of **semal** (Bombax Malabaricus) and **Falsa** (Grewia Asiatica), but these should only be used when the Hibiscus is not available. The scum (which is dark green in colour and is known in Rohelkhand as **dhandhoi** or **maill**) rises to the surface of juice undergoing clarification, followed, if clarification is complete, by an absolutely white froth which is called **chandoi.** If however the froth is not quite white, the inference should be that the liquor requires a further dose of the vegetable defecant, which should be added, though sparingly, till white froth begins to come up to the surface. Meanwhile the scum should be removed with the **pauna,** a round perforated disc of iron to which an iron handle is rivetted, and thrown with the same instrument on to a cloth or woollen strainer placed on a bamboo or wicker-work basket to serve as a filter, any liquor which goes with the scum being caught in a suitable receptacle placed below the filter. When a sufficient quantity of scum has accumulated on the strainer, it should be washed with water, which will carry any sugar down into the filtrate, leaving a worthless scum which may be given to the cattle or thrown away. The filtrate should, at intervals of a few hours, be returned to the process with fresh juice, and in this way very little sugar is actually lost. If before all the scum has come up, the juice shows a tendency to boil too violently or to overflow, the minimum of water necessary

ILLUSTRATION NO III

IMPROVED GUR AND RAB BOILING PLANT AND FURNACE GROUND PLAN

NORTH

Scale 4 ft = 1 in.



SECTION ON A. B.

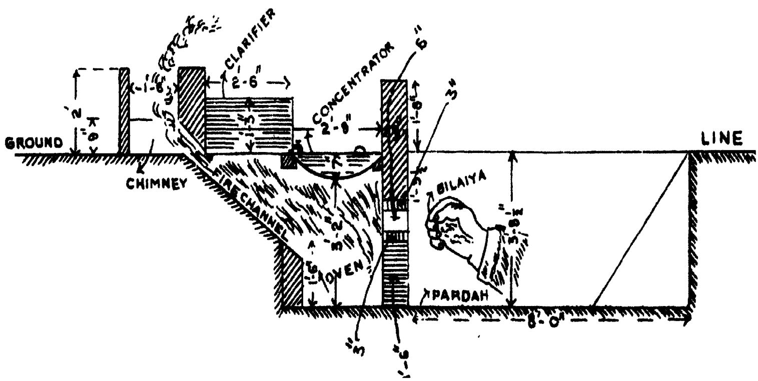
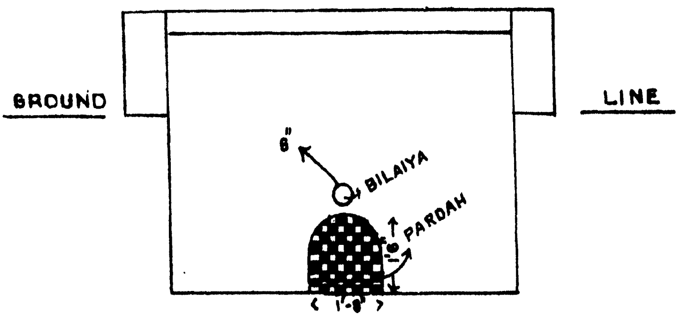
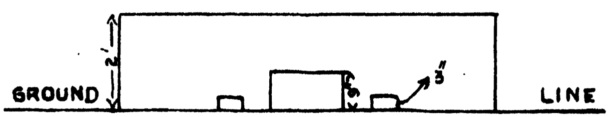


ILLUSTRATION NO. III (A)

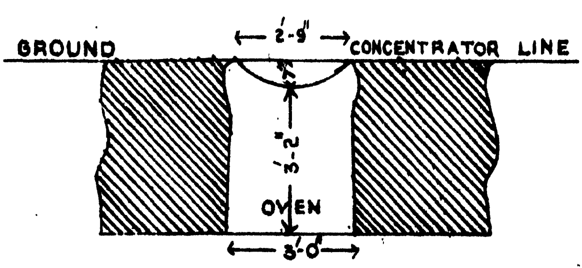
FRONT ELEVATION



BACK ELEVATION



SECTION ON G. H.



to stop furious ebullition may be added. It must be remembered, however, that every addition of the defecating material or of water must be boiled off which means the employment of more time, fuel and labour in the boiling and increased chances of inversion. The process of clarification should therefore be conducted with considerable caution. When all the scum has been removed, the white froth (**Chandoi**) will continue to come up to the surface. At this stage a solution of pink **sajji** (a mixture of crude sodium carbonate and some sulphur salt not actually determined, which is much weaker in action than the commercial carbonate or bicarbonate) should be poured into the boiling liquor in moderate quantity. With the evolution of the carbonic acid gas as a result of combination of the sodium with the organic acids present in the juice, an abundance of froth, which seems to consist chiefly of gummy matter contained in the liquor, then comes up violently to the surface. The sulphur salt also decomposes and the sulphurous gas evolved, which is readily perceptible to the smell, exercises a mild bleaching action on the liquor. It is for this reason that the solution of **sajji** is preferable to the carbonate or bicarbonate which contains no sulphur. Besides, strong alkalies favour inversion of crystallisable sugar, and impart a deep yellow colour to the concentrating syrup, and, is used in excess of a certain limit, spoil the quality of the **gur,** even when treating the juice from good canes. If the juice comes from canes of known inferiority, such as "lodged" canes, or diseased canes, or canes of over-luxuriant growth, due to excessive manuring or canes notoriously inferior in respect of sucrose content, such as, for example, the **Kansia** of East Bhopal, it would be very advantageous to add, at the advanced stage of clarification, a ladleful or so of clear saturated lime water for every tinful of juice. This treatment helps the solidification of the resulting **gur** very perceptibly. Clear lime-water, but not milk of lime, may be used in moderation with strong liquors too, but if employed in immoderate doses, the colour of the **gur** is sure to be inferior, though the crystals will be stronger. If the liquor is limed to the point of neutrality or thereabout, the **gur** produced is of a most undesirable colour specially if the pan is an iron one. Whatever may be said in favour of the liming process, the author after years of persistent efforts must deprecate strongly the adoption of the liming process in open-pan boiling except to the limited extent indicated above. Experience in dealing with the juice of each variety alone suggests the right quantity of saturated lime water to be put in the juice of each cane, the litmus test being of no avail as a guide.

Some canes, such as, for example, P.O.J. 33 (Lakhapur) contain a dark colouring matter in excessive quantities, and in such cases the clarified liquor is of a quite dark colour. This can be removed to a great extent by adding a few grains of sodium

hydrosulphite, a chemical much used for stripping fabrics of their colour in dye works. Its action in cleaning a sugar solution is instantaneous, but it is not readily available in India. In pre-war days it was sold in the Indian market under the commercial name of "Blankit" and used to come in from Germany. Now it can be got but at a considerably higher cost from England or from Indian chemical firms. Other chemicals, such as sodium sulphite and hyposulphite also improve the colour of the product but not as much as the hydrosulphite. An objection to the general adoption of this chemical is, that, if it is used immoderately, it imparts a yellowish tinge to the sugar crystals, which in case of **rab** meant for production of white sugar is a distinct disadvantage. The use of this bleaching agent by the villager in his cottage industry is not emphasised as the material is costly and a very superior final product can be obtained without its use, at least from all white canes.

When the clarification of the first charge of juice has been completed in the concentrator, it will be found that, if the whole of the quantity of the liquor in that pan is allowed to remain there for concentration, the pan would overflow. It is therefore necessary to keep a clean empty kerosene tin near at hand in which to ladle out part of the liquor leaving only such quantity in the pan as can be conveniently boiled without the risk of overflowing. As the liquor concentrates additions of clarified liquor should gradually be made to the concentrator to keep it boiling at its full capacity. By this time the juice in the large pan, the clarifier, should have received sufficient heat to bring about the rising of the scum to the surface. This juice should receive exactly the same clarification treatment as has already been described, and when completely clarified and quite transparent, with no particles of impurities floating in the liquid, it should be transferred to the concentrator from time to time in such quantity as is required by the latter to keep up its maximum capacity. If the clarifier is a flat-bottomed pan, there will be no charring of sugar during the boiling until only an insignificant quantity of the liquor is left in the pan, but if the clarifier is an ordinary bowl-shaped **karahi,** such as is generally used by confectioners, or in Indian kitchens and in the **bel** system of Rohelkhand, the sugar will begin to char round the edge of the boiling liquor, even while an abundant quantity of the liquor may remain in the clarifier. The reason for this untoward feature is obviously local over-heating of the pan and burning of the sugar, but it is avoided, at least until the operation is practically finished, by using a flat-bottomed pan.

It is really this trouble which spoils the quality and colour of the **gur,** because unless precautions have been taken, the situation is uncontrollable at that stage of the concentration and the charring of the sugar is inevitable. In order to obtain the best results it is therefore essential to anticipate matters by having ready,

in kerosene tins, clarified juice for the concentrator and fresh juice for the clarifier, so that the pans may be kept charged. When the final pan of the concentrated juice is nearly ready, the feeding of the furnace with fuel should be stopped and the charge in the concentrator should be stirred violently with the wooden instrument known as **ghotna.** The continuous movement of the liquid round and round keeps the temperature of the pan fairly uniform and prevents burning. The right condition or consistency at which to discharge a pan is judged by the cultivated eye, and the temperature of the mass is somewhere about 118° C. If the juice is from lodged or diseased canes or from canes naturally poor in sucrose contents the boiling is carried rather further in order to secure proper solidification, the maximum temperature varying from 119° to 122° C. according to the quality of the juice. Usually the temperature has not been taken in the Bhopal experiments for it is best to trust the trained boiler who seldom makes a mistake in determining the proper end condition. Corrections are always possible by adding a little boiled material of thicker or thinner consistency as the case may be. The pan should be removed from the oven with the hands and the contents ladled out on to the unbaked round earthen vessel known as **chak** on which the mass is allowed to cool. While the degree of heat in the concentrator is still low and the feeding of the furnace in abeyance, the concentrator should be re-charged quickly with clarified liquor and operations carried on as already described.

When the boiled mass lying on the **chak** has cooled down somewhat, it should be turned over with a wooden scraper (**Khurpi,** or **chandua**) until the mass assumes a spongy appearance when it should be made into a heap round or conical in shape and left to cool further. Portions may then be sliced off the heap and made into **battis** (cakes) of the special shape as fancied by the consumer, usually balls about 1/2lb in weight. The process of making such cakes is irksome and means unnecessary time and labour which could better be utilised otherwise. The Shahjahanpur system of making **bhelis** or **paris** each about 5 seers in weight should be adopted. For this purpose it is not necessary to waste as much time on turning the boiled mass over and making a heap of it. A baked earthen vessel, round in shape and known as **Kunda** is taken and a piece of clean cloth moistened with water spread round the inner surface of it. Slices of the cooling **gur** should be put over this cloth and when 4½ lbs. have been put in, the top should be covered with oblong pieces of scrapings of the crystallised crust formed on the surface of the **chak.** This operation gives the large finished cake a fascinating appearance.

At the end of the boiling operations for the day, the sugar sticking to the surface of the concentrator should be washed out with water, but the sugar solution (**dhandhoi**) so obtained is

claimed by workmen engaged as a matter of right. The skimmings from the concentrator are removed and collected separately and are known in Rohelkhand as **kaffi** as distinguished from **chandhoi,** the skimmings from the clarifier. The **kaffi** is prized as something most agreeable to the Rohelkhand villager's taste and presents of it are made to friends in the village community.

The fire in the ovens should be withdrawn by means of an iron shovel and extinguished with water for safety. The pans should be soaked in water without delay to dissolve away the remnants of sugar and thoroughly cleaned to prevent rust appearing. The quickest way of getting rid of rust is to wipe the surface of the pans with a piece of **tat** (gunny bag) moistened with sulphuric acid and then washing the pans with the lime residue taken from the tin containing saturated lime-water. Care should be taken to see that the acid supplied to the pan surface is completely neutralised before the vessels are used again for boiling. It is impossible in practice to completely avoid caramelisation of sugar when prolonged boiling is carried on and there will always be spots of caramel where there are slight depressions in the pan surface as well as incrustations due to deposits of salts at the bottom of the pans. These deposits and spots must be completely removed by mechanical means at least once a day or the pans will spoil the colour of the **gur.**

Having followed these methods the **gur** produced at the Bhopal Government Farm, during the past four seasons, was so uniform and superior in colour and other qualities that it has been possible to sell it in three out of the 4 seasons at 3 Bhopal seers, (7.4lbs) per rupee during the greater part of the season when the ordinary local produce was selling at 3½ and 4 seers to the rupee. In 1926-27 there was a considerable fall in the price of local **gur** in the Bhopal market on account of large imports of the article from Upper India. Even then the Bhopal Farm **gur** sold at four seers to the rupee against 5 seers per rupee, the price commanded by the common Malwa **gur.** On account of its richness in sucrose, the superior **gur** is said to become somewhat harder than the ordinary **gur** in the hot weather, and it has the great advantage of remaining unaffected by the moist atmosphere of the rainy season, whereas at that time the local **gur** becomes much softer in texture.

Unlike U. P. and other parts of Northern India, the Bhopal consumer's fancy demands that the **gur** should be more or less soft but rich in crystals, little value being attached to the light colour so much appreciated everywhere else. The local requirement can be easily met by finishing the boiling at a slightly lower temperature and allowing the finished product to cool on the **chak** surface a little longer, without stirring the mass, so as to

ensure formation of crystals perceptible to the naked eye. In this case the colour of the **gur** will not be so pleasing to the eye as when the striking point coincides with a higher temperature and other methods advocated in the foregoing narrative are followed.

We come now to the all important economic question of the cost of milling the cane and boiling the juice into **gur** as a cottage industry system. It appears that some obscurity exists as to the real cost of these operations. The Indian Sugar Committee have stated in para 296 of their Report that "the estimate of the cost of making **gur** given by different witnesses ranged from 1.87 to 2.5 annas per maund of cane." Crop cutting experiments were conducted most carefully in two of the best sugarcane growing tracts of Bhopal with average crops of the three main varieties of cane, with a view to determining (a) the average outturn of raw sugar per acre and (b) the cost of crushing and boiling operations actually incurred. The following account of the cost has been drawn up on the basis of actual figures obtained in course of the experiments :—

Cost of manufacturing gur as actually ascertained by crop cutting experiments in the Ashta and Ichhawar Parganas of Bhopal State.

Variety of cane.	Area in Acres.	No: of canes.	Weight of canes in Bhopal Mds. (98.7lbs=1Md.)			Weight of canes in Standard Maunds (82.2lbs.=1Md)		
			Mds.	Srs.	Chs.	Mds.	Srs.	Chs.
(1) **Munhtora**	1	1,13,000	271	32	8	326	7	0
(2) **Mandkia**	1	58,000	290	0	0	348	0	0
(3) **Bhelsai**	1	57,000	342	0	0	410	16	0

As it is customary to grow all the three canes mixed, the average produce of cane in Standard Maunds calculates as follows :—

Mds.	Srs.	Chs.			Mds.	Srs.	Chs.
326	7	0					
348	0	0					
410	16	0					
1,084	23	0	divided by 3	=	361	21	0

Reducing the above figures to the Bhopal Bigha, which is 7/10ths of an acre, the produce comes to

	Mds.	Srs.	Chs.	
(361 Mds. 21 Srs.) ×7/10=	253	2	11	cane per Bigha by standard weight.
	Mds.	Srs.	Chs.	
or	210	35	9	by Bhopal weight.

Yield of **gur** from the above quantity per acre.

	Bhopal weight. Mds.	Srs.	Chs.	Std. weight. Mds.	Srs.	Chs.
(1) **Munhtora** ..	29	0	0	34	32	0
(2) **Mandkia** ..	31	20	0	37	32	0
(3) **Bhelsai** ..	36	10	0	43	20	0

The average daily production of **gur** using one three-roller mill and one pan working day and night, as is the custom in Bhopal, is 2 Bhopal maunds and with inferior canes still less. The tenants, as a rule, do not work with more than one mill. Therefore, the above quantities can be prepared in the number of days as calculated below :—

(1) **Munhtora** Mds. 29. divided by 2=14½ days.
(2) **Mandkia** Mds. 31. Srs. 20 divided by 2=15¾ days.
(3) **Bhelsai** Mds. 36. „ 10 „ „ 2=18 1/8days.

The cost of working a furnace with one mill day and night to produce 2 maunds of **gur** (Bhopal weight) is detailed below :—

	Rs.	As.	P.
Mill hire	1	0	0
Hire of two pairs of bullocks	2	8	0
Wages of 4 men working during the day	1	4	0
Wages of 8 men working during the night (four during the 1st half and 4 during the 2nd half)	1	8	0
Lamp oil	0	1	6
Lubricating oil	0	1	3
Khankhari fuel (Butea Frondosa)	1	0	0
	7	6	9

Add the quantity of **gur** given to workmen and the mill-owner in accordance with the village custom :—

	Srs.	Chs.
(1) To 8 men working during the night, at 6 **chhattaks** per head	3	0
(2) To Carpenter	0	10
(3) To Blacksmith	0	10
(4) To Potter	0	7
(5) To the mill owner	0	8
Total **gur**	5	3

The value of the above **gur** calculated at 4 Srs. per rupee amounts to	1	4	9
Total Rs. ..	8	11	6

The cutting and stripping charges of cane at 16,000 per rupee plus three seers of **gur** for every rupee paid are as follows:—

Variety of cane.	Number of canes per acre.	Cash paid on account of cutting and stripping.			**Gur** given		Value of **gur** given.			Total		
		Rs.	as.	ps.	Srs.	Chs.	Rs.	as.	ps.	Rs.	as.	ps.
Munhtora	1,13,000	7	1	0	21	3	5	4	9	12	5	9
Mandkia	58,000	3	10	0	11	1	2	12	3	6	6	3
Bhelsai	57,000	3	9	0	10	11	2	10	9	6	3	9

Average cost per acre. (Rs. 12-5-9) + (Rs. 6-6-3) + (Rs. 6-3-9.) divided by 3 = Rs. 8-5-3.

Two Bhopal maunds or 2.4 Standard Maunds of **gur,** the daily output of the Bhopal manufacturer, represent according to the averages of yield given above 18.6 Bhopal Mds. or 22.3 Standard Maunds of cane.

Assuming on the above basis Rs. 8-11-6 to be the total cost of milling the cane and converting the juice into **gur** by the local methods, the cost of production of **gur** in Bhopal calculates to 6.2 annas per standard maund of cane or Rs. 3-10-1 per standard maund of **gur.**

Comparing these figures with those quoted by the Indian Sugar Committee viz. 1.87 to 2.5 annas per maund of cane it is easy to understand why the prices of **gur** rule so high in Malwa, and what a scope there is for efforts to reduce the cost by improving the method of boiling.

Such is the actual cost incurred by the **gur** manufacturer of Malwa with whom we are mainly concerned at present, and the figures probably hold good for the greater part of Central India. It has been unreservedly recognised by the numerous critics who have seen the Bhopal demonstrations, that the colour and the quality of the **gur** produced under the improved method are incomparably superior to any other Indian specimens of **gur,** and

that the money value of the outturn is, on that account alone, unquestionably greater than before. At the same time the cost of the production by the recommended process has been carefully watched, studied and controlled with the result that roughly speaking it is about 19 per cent less than the cultivator's cost, if a boiling plant corresponding to a single 3-roller mill is worked and about 39 per cent less, if a plant to suit two 3-roller iron mills is worked.

The following is a detail of the cost where only one 3-roller 8″ bullock-power mill working 10 or 11 hours a day with a corresponding set of improved pans is used, to boil the yield of juice in about 14 or 15 hours.

	Rs.	a.	p.
Hire of one 3-roller crushing mill	1	0	0
Hire of 2 pairs of bullocks for working the mill. ..	1	8	0
2 labourers for driving the bullocks and feeding the mill	0	12	0
2 men to attend to the pan (trained boilers).. ..	1	0	0
1 assistant to the above	0	6	0
2 furnace-feeders	0	12	0
1 extra labourer for making balls &c.	0	6	0
Fuel over and above the bagasse (if necessary) ..	1	0	0
Defecants etc.	0	2	0
Lamp oil	0	1	0
Lubricating oil	0	1	3
Cost of construction of furnace etc. spread ever 100 days	0	1	0
Blacksmith's dues (usually paid in **gur** at 10 **chhattaks** a day for attending to the mill)..	0	2	6
Carpenter's dues for attending to the mill	0	2	6
Potter's dues (7 **chhattaks** of **gur** for supplying **chak** and other earthen vessels)	0	1	9
Mill-owner's dues in gur (8 **chhattaks**)	0	2	0
Interest at 12% on the capital invested on pans (say Rs. 25/- spread over 100 days)	0	0	6
Depreciation 12% on capital spread over 100 days ..	0	0	6
Total ..	7	11	0

The total output of **gur** of the day working as above will be 3 standard maunds, crushing 24 to 25 maunds of cane.

The cost of manufacturing **gur** per standard maund of cane and per standard maund of **gur** will be as follows :—

Per maund of cane

Rs. 7-11-0 divided by 24.5.
= Rs. 0-5-0.

Per maund of gur.

Rs. 7-11-0. divided by 3
= Rs. 2-9-0.
Rs. 2.56.

If somewhat larger pans such as those shown in illustration No. III be employed, which would mean raising the capital expenditure from Rs. 25 to Rs. 90, the cost of manufacture will be greatly reduced, as the larger pans will then be capable of dealing with double the amount of juice, viz juice expressed by two three roller mills of the capacity employed in the above case, without increasing in any way the cost of boiling, but with increased expenditure on crushing, as will appear from the figures given below :—

	Rs.	a.	p.
Cost as detailed above in case of single three-roller mill	7	11	0
Hire of one additional mill	1	0	0
Hire of 4 bullocks to work the additional mill ..	1	8	0
2 labourers for working the above mill	0	12	0
Blacksmith's dues **in gur** (10 **chhattaks**)	0	2	6
Carpenter's dues in **gur** (10 **chhattaks**)..	0	2	6
Mill owner's dues in **gur** (8 **chhattaks**)	0	2	0
Potter's dues in **gur** (7 **chhattaks**)	0	1	9
Lubricating oil for the additional mill	0	1	0
Defecants etc.	0	2	0
Depreciation on additional capital Rs. 65	0	1	3
Interest on .. do do do	0	1	3
Lamp oil	0	1	0
Total ..	11	14	3

With the above cost, the quantity of **gur** prepared will be 6 Standard Maunds, crushing 48 to 50 maunds of cane. The cost per Standard Maund of cane and **gur** will be :—

Per Standard Maund of Cane.	Per Standard Maund of **gur.**
Rs. 11-14-3 divided by 49= Rs. 0-3-10. = 3.8 annas.	Rs. 11-14-3. divided by 6 = Rs. 1-15-8. = Rs. 1.98

It must be observed that in the above accounts the hire of a 3-roller mill, which, by the way, is ordinarily of an inefficient type, at R.1. per day, is an unduly high charge open to objection on grounds of economy. The Hathi mill constructed by Messrs Burn & Co., Calcutta, can be landed in Bhopal at a cost of Rs. 135/- and a Chattanooga mill from Bombay which is perhaps more efficient at about Rs. 160/- or the Kisan at the same cost. It would thus be a distinct gain to the manufacturer to purchase one or more of these mills and the cost of hire for a little more than one working season will cover the initial investment.

At Sehore in Bhopal three-roller mills manufactured and hired out annually by a local iron-founder are nearly as efficient as the three mills just mentioned but are not so well finished.

The question of making **gur** on a large scale using a power plant for crushing and improved pans and furnaces for boiling the juice, is one of such great economic importance that a separate chapter has been devoted to it in this book (vide chapter XIII, considering that the subject was one of special interest to the capitalists and cane-growers of Malwa, where as an article of food the **gur** is valued to such an extent that the orthodox villager willingly pays as good a price for the same as the Java sugar commands in Calcutta and Bombay.

B. Manufacture of KACHCHA BURA.

In the course of the Bhopal experiments it was discovered that the juice of some of the exotic and seedling canes, specially Manjav of Manjri and S. 48 of Shahjahanpur Farms possessed, as a result of their great purity and richness in sucrose, the unique property of being capable of conversion into a form of mealy sugar when boiled to somewhat thicker consistency than for making **gur.** To get this result, at its best, it is desirable to have the top portion of the cane, which is not so rich in the sucrose as the rest of the stem, cut off and used for planting. If the cane is unripe, rather more should be cut off, say two pieces, each 12" or 15" long. It would not be uneconomic to do so, as the top, though comparatively poor in sugar, is the best part of the cane for seed purposes. The juice from the canes without their tops, should be defecated, as for the preparation of **gur** or **rab,** but more thoroughly, milk freely diluted with water being also used for clarification, and if the liquor is pink in colour, as is often the case with S. 48 juice, it should be bleached with a very small quantity of sodium bicarbonate, or sodium hydrosulphite. This chemical treatment is however by no means essential. The liquor should be boiled as for **gur,** care being taken to remove the scum (**kaffi**), as it accumulates on the surface. When the final consistency has nearly been attained, the feeding of the furnace should be stopped, and the boiled mass should be stirred vigorously with the **ghotna** till the point of heavy stickiness is reached, when the pan should be removed from the oven and placed over a shallow depression made in the ground, so that the pan may not shake in the crushing operation to follow. As and when the mass loses its heat, it should be treated as described for **bura** making (vide chapter XVII).

The resulting sugar is very light in colour at its best, and generally pale yellow, the yield being about 18 per cent on the weight of juice. The lumps (**turri** or **rori**) removed on sifting the crushed mass are thrown into the next pan on removal from the fire. This new form of sugar was so well appreciated by the rural population of Bhopal, that it could be sold at Rs. 15/- per local

maund (48 standard seers or 98.7 lbs.), when the best **gur** of Farm produced by the improved methods, was selling at Rs. 13-5-4 per local maund.

As this form is a new comer in the sugar world of India, it had to be given a name and we have christened it **kachcha bura.** The indigenous canes of Bhopal, and, in fact, those of the whole of Upper India, that the author is familiar with, are not amenable to this treatment. If they are treated similarly, the resulting product will be only **gur,** or a mass of irregular shaped lumps, which would fetch no better price in the bazar than the common **gur.** This admirable property of being able to convert a thickly boiled juice into a powdery sugar, is peculiar to Manjav and S. 48, and, in a distinctly less degree, to Co. 214 and Co. 221.

There is no doubt that a form of crushed sugar prepared direct from the juice, which goes under the name of **shakar-i-surkh,** is known on the Meerut Division and parts of Rohelkhand, but it is a dirty and gritty stuff owing to the fact, that **reh,** the well known crude natural form of sodium carbonate sodium sulphate and sodium chloride, is used in unduly large quantities to neutralise the acids contained in the boiled mass before it is ready to crumble. The final product is therefore more or less disagreeable to the taste and has further the objectionable property of deliquescing when exposed to the air in the rainy season. Reference may be made to pages 74 to 75 of "The Sugar Industry of the United Provinces of Agra and Oudh" for details of the manufacture of **Shakar-i-surkh** in the U. P.

The discovery of this new form of sugar is an acquisition for the cottage industry of India, and should go a long way towards helping the introduction of Manjav and S.48 into Indian Agriculture, and the rapid extension of their cultivation, where they have already been introduced. This result is bound to follow when this extraordinary property of the two canes, which arises from the purity of the juice, becomes more widely known in the country. Manjav yields a better quality of **kachcha bura** than the other varieties.

CHAPTER XI.

Manufacture of RAB.

Rab is a semi-liquid product obtained by boiling the juice to a slightly lower degree of concentration than for the preparation of **gur.** It is manufactured for the sole object of producing white sugar (**khand**), and it is made chiefly in the Rohelkhand and Meerut Divisions, where the Indian white sugar industry is still struggling for its existence, and to a less extent in the eastern parts of the United Provinces. **Khand,** besides being used by the confectioner, forms the basic material for making the higher grades of refined sugar known as **Bura, Qand** and **Misri.** No white sugar is made in India except from **rab** or by refining **gur.** The product from the latter, called **"chini"**, is made in factories in Behar, Oudh and the Eastern Districts of U. P., but the methods of refining are far more wasteful than those followed by the **khand** manufacturer. So long, therefore, as an indigenous white sugar industry exists in the country, which it will do because of the purity of the country sugar in the religious sense of the term, the manufacture of **rab** is bound to be an important consideration in the Indian sugar industry. The **rab** making industry has still a long life before it, and improvements in its manufacture cannot therefore be ignored.

The manufacture of **rab,** as carried out in Rohelkhand and Meerut, is unknown in Bhopal. There, the strongest juices are utilised for **rab** production; here it is the weakest juices, incapable of yielding typically solid **gur,** that are converted into a liquid product hardly deserving to be called **rab.** In other words, when the cultivator finds that his **gur** does not solidify properly, he boils the juice into a syrup, which when potted and stored for some weeks or even months, crystallises partially; but the yield is so poor and the crystals so fine, that the attempt to extract sugar from this so-called **rab** cannot pay for the cost of operations, nor will the sugar so produced with the centrifugal be white. The basic article produced in Bhopal is a very dark material comparing most unfavourably with even the inferior specimens of **rab** made in Upper India, and shows a deplorable ignorance of this part of the craft. It is therefore in this branch of sugar industry that the manufacturer in Malwa badly needs education, and in this chapter instructions for making **rab** are given which will be of value to the Upper India manufacturer as well as the inhabitants of Malwa, for none of the processes in use are perfect.

While it must be admitted that in view of economy in the fuel and gain in the output, the Rohelkhand **bel** is an admirable contrivance in its present form for boiling the cane juice into **rab** at the minimum cost, it must also be pointed out that it is seriously defective in several respects. As a result of the existing defects the arrangement is incapable of producing massecuites of uniform richness and strength throughout its working. Each strike (**chashni**) discharged from the finishing pan or the **parchha** contains more caramelised and inverted sugar than its predecessor, and in consequence, whether the **rab** is treated by the old method under the **khanchi** system or according to the practice which has been gaining ground during the last two decades, in a hand or power centrifugal not uncommonly in use in the Rohelkhand industry now, the resulting "white" sugar (**khand**) is not only a low grade product in quality, so far as the colour and crystals are concerned, but the yield of the same is so unsatisfactory that it fails to inspire the manufacturer with the hope, under adverse market conditions, of holding his own in competition with foreign or Indian sugars produced under modern scientific methods. Thirty five per cent of low purity **khand** with perceptible adherence of a thin film of molasses on the fine sugar crystals, and an objectionable characteristic flavour suggesting the smell of molasses, even when bleached and dried in the sun on the **pata,** is about the maximum limit obtained in Bareilly from the **rab** made in the Rohelkhand **bel** when treated in a 30" power centrifugal. Owing to the presence in it of an undesirable percentage of molasses in an adhesive state, this product usually forms lumps after storage, a feature which reduces the market price of the sugar. In Shahjahanpur where the hand power centrifugals are worked by the **khandsaris** through labourers employed on contract system, the yield of sugar is higher, but the quality is so inferior that the final product should more appropriately be called brown rather than white sugar. It sells cheaper than the better quality "machine sugar" of Bareilly. Under the **khanchi** system the percentage of the yield is quite distinctly lower with corresponding waste of sucrose, though the quality of a certain part (the **phul**) of the yield is comparatively good. It is mainly on these grounds that the open-pan system of sugar-making has hitherto been looked upon with indifference or even disfavour by the recent investigators, who seem to have treated the system very lightly from the beginning and assumed the existing **bel** to be as perfect a **rab**-producing machine as it could be, without closely examining it.

It has however been found by careful study of the technique of the Indian **bel** that these defects are by no means irremediable and the object of the following observations is to discuss in some detail, even at the risk of prolixity, how matters stand at present and how improvements, if any, could be brought about. For

this purpose, it is necessary in the first instance, to try and understand the object and principles which originally guided the illiterate masters of the Indian boiling art, in absolute ignorance of the bearings of the physical and chemical sciences on their processes, when they were determining the dimensions of the various ovens constituting the furnace and working out other details.

Ordinarily the Indian **bel** owner is a mere business man, and no expert in the art either of building the furnace or boiling the juice. He concerns himself mainly with the management of his refinery and its accounts, leaving the supervision of the boiling department to a **Darogha,** usually a low-paid layman. The best of these supervisors is more anxious to show a large daily output to his master than to see that the quality of the finished material leaves nothing to be desired. The manipulation of the juice is thus practically left to the mercy of the boiler. Bad economy is generally exercised in selecting these artisans; skilled professional boilers being seldom employed because of their charges which are comparatively high. The work is entrusted generally to craftsmen accredited merely with a superficial knowledge of the elements of the boiling art instead of the skilful **Halwai** whose assistance is only invoked under most pressing conditions, for example when the cane to be dealt with is particularly poor in sucrose and the yield of **rab** very bad. Where the professional **Halwai** who knows the higher details of the art is engaged, he takes good care to keep all the secrets of his craft to himself in showing better results to the employer, who thus remains always ignorant of the real causes of the superior outturn. In view of these circumstances it seems necessary that a complete exposition should be made of the details which the expert is usually reluctant to disclose to the un-enlightened employer, so that the observations made hereafter may be of use to the proprietor in controlling his employees on the technical side, on the successful working of which depends materially the success of all subsequent operations.

The first object of the ingenious inventor of the **bel** was to avoid any influence of the prevailing wind over his furnace. In Rohelkhand the wind which blows most commonly during the boiling season (winter) is westerly. Occasionally when the weather is cloudy, prior to the winter rains (**Mahawat**) which may or may not come, the direction of the wind is easterly. If the **bel** were to face west, the rush of the prevailing wind into the furnace through the feeding hole, would render the proper boiling more or less out of control, as there will be too quick a rush of the heat along the channel over which the flames travel up to the chimney and onwards, with the result that the last or the finishing pan (**parchha**) will fail to receive its desirable share of heat, while the other pans will get more than is required. When the prevailing wind,

ILLUSTRATION NO. IV

THE ROHELKHAND BEL SYSTEM OF BOILING PANS

GROUND PLAN

Scale 8ft = 1"

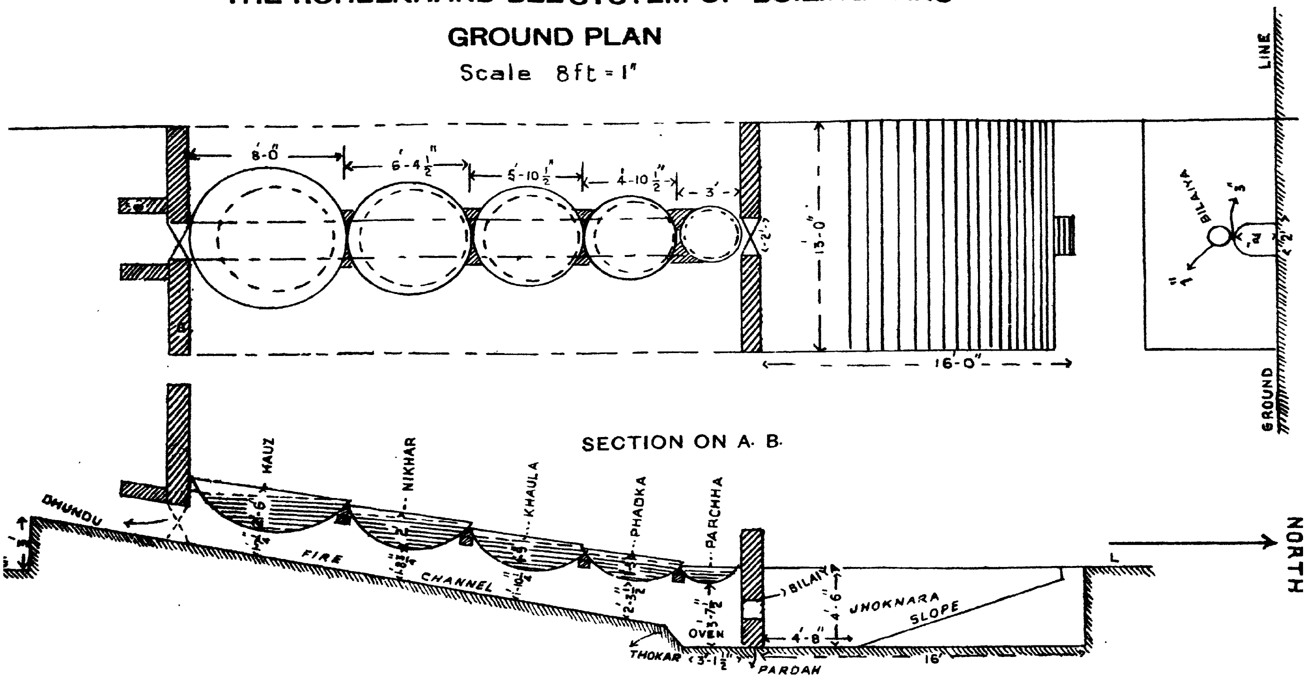
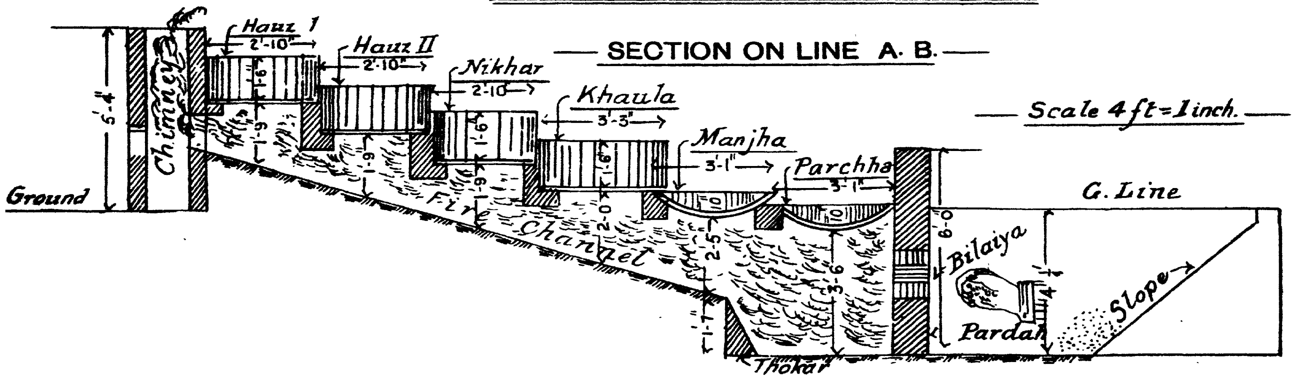


ILLUSTRATION NO. V

IMPROVED SUGAR BOILING FURNACE

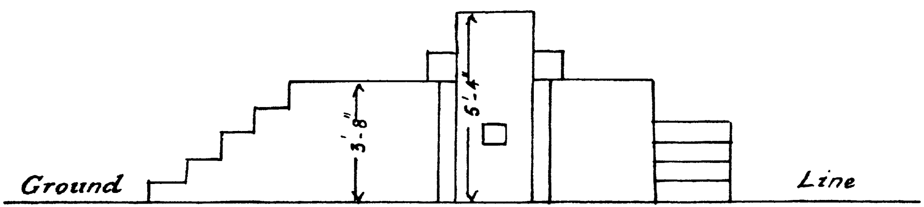
SECTION ON LINE A. B.

Scale 4 ft = 1 inch.



BACK ELEVATION ON C. D.

NORTH



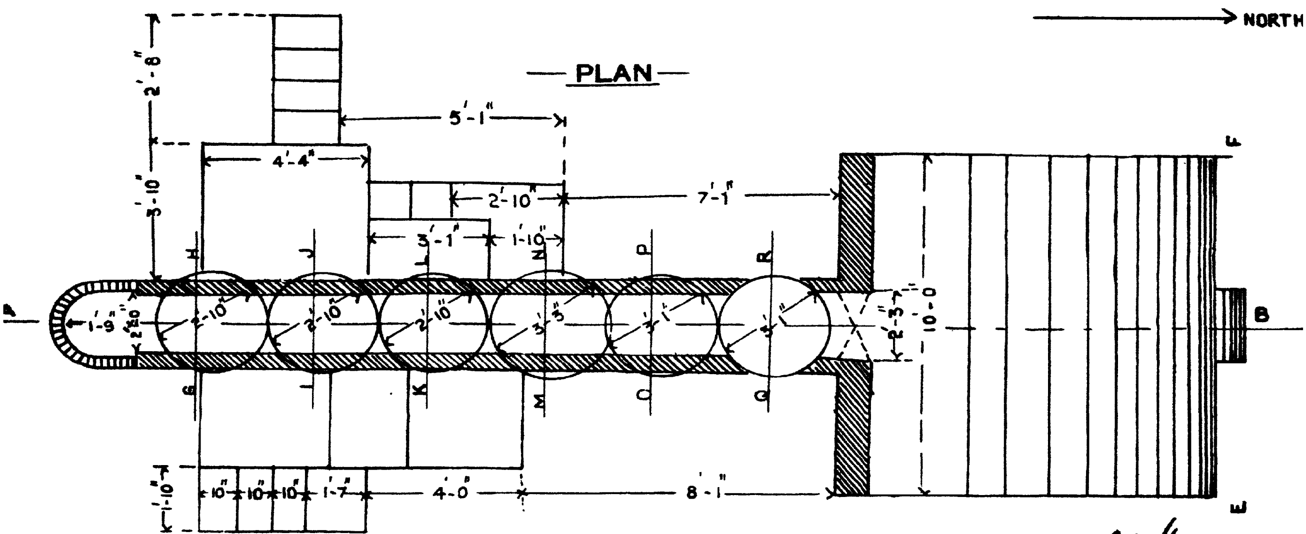
Chief Engineer
P. W. D. Bhopal.

Drawn by
Md Yusuf Ali
Head Draftsman

ILLUSTRATION NO. V (A)

IMPROVED SUGAR BOILING FURNACE

Scale 4 ft = 1 inch.

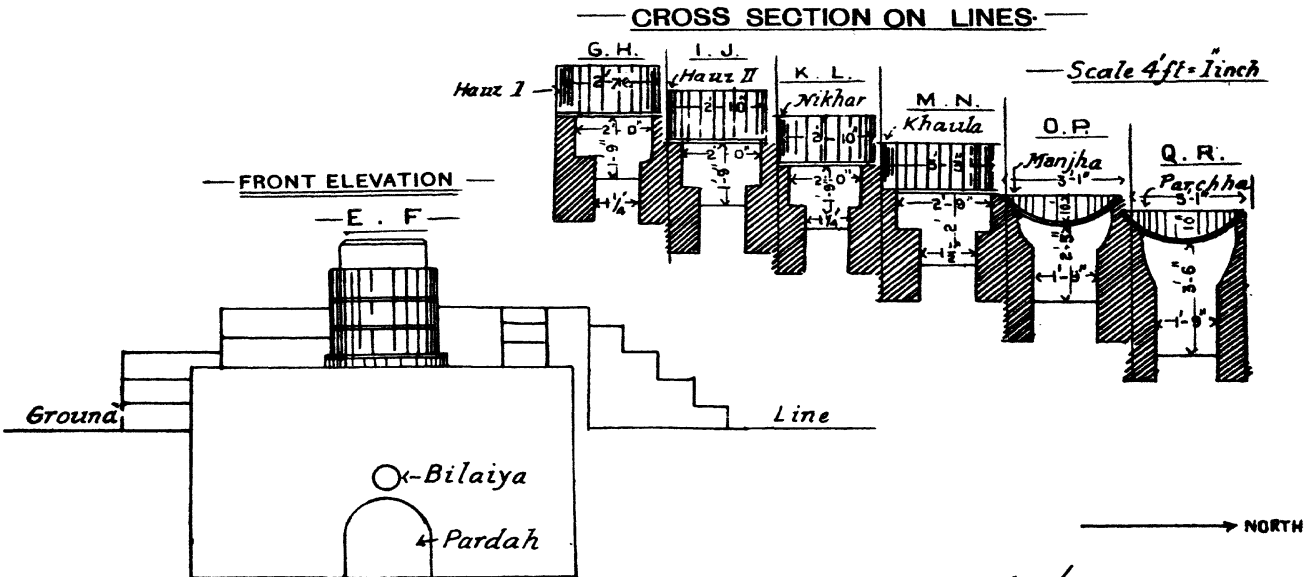


Drawn by
Md. Yusuf Ali

Chief Engineer
P. W. D. Bhopal.

ILLUSTRATION NO. V (B)

IMPROVED SUGAR BOILING FURNACE



Drawn by
Md. Yusuf Ali
Head Dftn. P.W.D.

Chief Engineer
P.W.D. Bhopal

under these conditions happens to be easterly, the flames in getting out of the chimney will, in resistance of the force of wind, be thrown back into the said channel and escape partially backwards through the feeding orifice (**bilaiya**), thus rendering the feeding difficult for the furnace feeder, and interfering with the undisturbed progress of the boiling otherwise. Northerly and southerly winds are rare during the boiling season. It has therefore been made a hard and fast rule to make the **bel** face the north, and no deviation from it is allowed. The aerial conditions of the weather in Malwa during the cold season being similar to those of Rohelkhand, the rule should be equally rigidly followed in this part of India.

In order to be able to understand easily the construction and working of the Rohelkhand **bel** and to form a clear idea of the improvements embodied in the new arrangement for boiling **rab**, the reader is requested while perusing the following observations to refer to Illustrations IV, V, V (a) & V, (b) as often as may be found necessary so that the details of the two systems and the reason for each modification may be fully grasped.

For reasons given in the foregoing narrative the first excavation of the Rohelkhand **bel** (Illustration IV) in the north is the rectangular pit known as "**Jhoknara**" which is ordinarily from 14 to 16 feet long and 11 to 13 feet wide at the surface, and from 4 to 4 feet 8 inches deep with a slope of 11½ feet running towards south and ending at a distance of 4 to 4 feet 8 inches from the wall containing the feeding orifice. The object of this excavation is two-fold. In the first place it provides room for storing the fuel, whatever it may be, and the room for the feeder (**jhonka**) to sit in. In the second place it induces, being adjacent to the hottest oven of the **bel**, a continuous but calm rush of cooler atmospheric air into the pit, as the combustion of the fuel in the said oven proceeds, which gives rise to a draft of normal strength sufficient to force the flames produced in the oven, right up to the chimney and outside, the formation of the draft being further helped and controlled by means of the **pardah**, [to be described presently]. Immediately adjoining the **jhoknara** is what is called the **pardah** wall which is, up to the ground level, about 4ft to 4 ft 8 inches high from the bottom surface of the pit towards south of the **jhoknara**. In Rohelkhand this wall is not ordinarily built with bricks in mud, but on account of softness of the alluvial soil it is brought into existence by scraping the earth on one side of the **jhoknara** and on the other of the adjoining oven, and the thickness of the wall is only three inches at the place where the feeding orifice is cut through, though the wall above the ground surface is much thicker. Such a procedure would be impossible in Malwa where the soil is harder and not friable. Here it is essential to build up

an equally durable wall about 9 inches thick with sun-baked bricks. The thinner this wall, the more efficient the action of the heat is believed to be, but a wall of sufficient thinness consistent with the necessary strength, is an impossibility in Malwa, where the minimum thickness capable of standing the strain should be 9 inches. At Bhopal a two-inch thick **pardah** wall made of kiln-baked bricks but having a thickness of only 1½ inches at the feeding orifice (**bilaiya**) has been tried for a whole season with success, but the orifice used to give way and had to be repaired about twice a week. The combustion of the fuel was, however, so perfect as to render it worth while putting up with the disadvantage. At the bottom of this wall, there is the arch known as **pardah,** a semi-circular structure made in Rohelkhand by cutting a chord-like hole through the wall by means of the **khurpi** (scraper) and in Malwa with bricks, preferably baked ones. The arch is partially closed daily before the commencement of the operations by means of temporary lattice work made with pieces of stones and bricks, the ends of these pieces being partially plastered in places with mud, so as to leave small holes through which the natural draft should pass into the oven to aid the combustion. The height of the **pardah** arch in Rohelkhand is about 1 ft. 10 inches and the width at the bottom about 2 ft.

When thick logs of wood have to be used for fuel, as is sometimes the case, before the bagasse is available for burning, the **pardah** arch may be kept open and the **bilaiya** closed, but when the bagasse and the trash or small pieces of firewood form the fuel supply, the **pardah** arch must be closed in the above manner. If the arch is so closed the flames in the first oven below the **parchha** would rise almost perpendicularly furnishing the largest amount of the heat to that oven. If any of the pans higher up are found to be receiving less heat than is necessary, the holes in the bricked arch should be made wider, which can easily be done by removing part of the plaster in places or removing some of the smaller stones or pieces of bricks. Greater rush of the draft upwards which will carry more heat to the desired pan is thus secured. A third object of the pit is to provide room for removing the ashes when necessary and extinguishing with water whatever fire there may be in them. In a properly erected **bel** it should not be necessary to take out the ashes until after 8 or 10 hours of continuous boiling.

About three inches above the circumference of the arch there is a circular hole about 6 to 7 inches in diameter known as "**bilaiya**" (feeding orifice). In Rohelkhand the inner circular surface of the orifice is strengthened by inserting the mouth of a well-baked **Kalsi** (**rab** pot) broken off that vessel. In Malwa, a circular ring made of thin sheet iron about 1½ inches in width and 6 inches in diameter should with advantage take the place of the mouth of

the **Kalsi,** otherwise the **bilaiya** would wear out too quickly, the orifice will become widened and proper distribution of the heat in the furnace will be seriously hindered. This orifice should likewise be plastered round inside and outside with fresh mud every day before the boiling is started. The earth used for plastering should preferably be of the kind known locally as **pili matti.**

The inner construction of the **bel** furnace may now be considered. As dry bagasse is the main fuel to be used, the **bilaiya** has been so designed as to admit of incessant feeding with as much of that material as the feeder can conveniently hold in his hand at a time. The fuel collects in the oven immediately below the finishing or the last pan (**parchha**) and undergoes combustion which is constantly helped by the natural draft passing into the oven through the **bilaiya** and the holes in the **pardah** arch. It is obvious that the quantity of fuel entering the oven in this manner will produce a certain number of thermal units and no more, and that this amount of heat will boil and concentrate only a certain amount of saccharine liquids and no more, one part by weight of the bagasse fuel, dead dry, having been found by repeated trials to suffice for boiling, 3 to 4 parts by weight of juice to the consistency of **rab.** Should the furnace demand more fuel, it should be concluded that there is a mistake somewhere in the construction. It would thus be a futile persuit to attempt boiling a larger quantity of juice with the available calorific energy. Such effort is bound to be followed by undue inversion during the boiling process and consequent deterioration in the quality of the finished product, as is generally the case where the standard **bel** system of Rohelkhand is followed literally. It is in determining the dimensions of the upper pans that the worthy inventor of the **bel** has gone astray. These are huge vessels which are usually charged with quantities of juice too large to be **concentrated** with due rapidity, with the application of the limited amount of heat travelling upwards from the oven. The chief aim is to supply the largest amount of heat generated in the above manner to the **parchha** pan, and to utilise any balance left thereafter for heating the remaining four pans higher up. The oven is therefore more or less spheroidal in shape inside with curves called **"dano"** in its eastern and western walls within, as shown in Illustration V (b). The bottom of the oven which is perfectly even and level, is rendered strong and durable by making a pavement of brick-on-edge work and plastering it over with plastic mud. The perpendicular distance between the bottom of the pan and that of the oven varies from 3ft. 6 inches to 3ft. 7½ inches so that the total perpendicular height from the bottom of the chamber to the top diameter of the pan amounts to about 4ft. 5 inches, or 4ft. 6½ inches, the depth of the parchha being about 9 inches and its thickness at the bottom about 2 inches. In Rohelkhand the pan is sometimes so placed on the

oven that the upper edge is sunk into it several inches below the ground level. This is open to objection, because the earth from the surrounding ground unavoidably washes into the pan during the boiling operation and gets mixed with the liquid. In the improved form (vide Illustration V), this defect has been remedied by placing the pan over the oven in such a manner, that the upper edge of the pan is in a level with the surface of the ground. With a view to imparting the maximum amount of heat to this pan, some expert furnace builders go so far as to carve out an arch in the southern surface of the **pardah** wall, so as to find space for pushing the pan three or four inches onwards into this arch, in order to make its position as near the **bilaiya** as possible. Between this pan and the one higher up there is an arch made of unbaked bricks on which the southern end of the pan is made to rest. The builder then enters the chamber through the **pardah** arch and closes with mud the open spaces left between the pan and the arch towards the south and between the pan and the **pardah** wall towards the north. The chord of the arc in the lower part of the pan left exposed to the direct action of the flame is thus only about 2½ feet, although the top diameter of the pan is 3 feet or 3 feet 1 inch. The mud plastering done in order to close the open spaces just mentioned is technically known as **"Sancha"** (mould) or **"got"**. (hemming). It is into this ring of plaster (vide Illustration V (b) that the pan is, so to say sunk. The bad conductivity of the plaster clay minimises the charring of the sugar, so long as the surface of the boiling liquid inside the pan is above the portion of the pan directly in contact with the flames. This pan which should be shallow must be made of extra thick pieces of wrought iron, in preference to sheet iron, the latter being liable to get overheated in course of continuous boiling which forms the chief characteristic of the operations, and therefore there is greater risk of charring in a sheet iron vessel than in the other. The depth of the pan should vary from 8 to 10 inches and the vessel should weigh about three imperial maunds. The inner surface of the pan should be as smooth as possible. In a badly constructed pan there will be crevices at the joints of the various pieces rivetted together to form the pan, which harbour the caramelised sugar, giving rise to deterioration in the quality of the **rab.** If, therefore, the aim is to prepare a massecuite of superior quality, it is essential that the inner surface of the pan should be even. There are expert professionals in Bareilly and Shahjahanpur who make excellent pans of this type. Intending sugar manufacturers outside Rohelkhand will be well advised to get pans of this type made to order by one of the Rohelkhand workshops instead of trying to have them made locally. Ready-made pans sold in the bazars of Rohelkhand are inferior generally. The bottom central piece of the pan is about 2 inches thick, the upper pieces are of decreasing thickness, the top pieces being about ¼ of an inch thick.

At a distance of three feet 1½ inches from the **pardah** wall towards south and within the oven begins a slope called **"thokar"** going upwards, which is about 1 ft. 7 inches in length and ends at a perpendicular height of about 1 ft. 5 inches from the bottom surface of the oven. At this point begins the channel (**nali**) through which the current of the flames not used up for the benefit of the **parchha** travels upwards and imparts heat to the remaining pans in its course. This channel is about 30 ft. long and has a uniform width of 24 inches, the depth at the bottom of each pan decreasing with the rise of the channel upwards. In the new arrangement (Illustration V) the **thokar** begins at the same distance from the **pardah** wall as in the Rohelkhand system but the slope is about 1 ft. 9 ins. in length and the vertical height about 1 ft. 7 inches. If in any individual case it is found that with a **thokar** of the above dimensions the distribution of heat in the various ovens is not as good as is required, the professional boiler who understands the Rohelkhand furnace will be able to modify the dimensions, so as to meet the actual requirements.

The point to be carefully kept in view is that the **thokar** plays a very important part in proper distribution of the heat generated, and it should be so constructed, with reference to its slope and vertical height, that the greatest calorific advantage may be derived from the flames when passing upwards along the fire channel.

The next higher pan of the Rohelkhand **bel** known as **"phadka"** (from **"phadakna"** to form bubbles) is nearly two feet wider in diameter and about 8 inches deeper with equally thick bottom plates, the wall being made of thinner pieces than for the **parchha.** This is placed on the next oven up above on a brick-made arch close to the **parchha** on one side and a similarly constructed arch on the other towards south, the perpendicular distance between the bottom of the vessel and the upper end of the slope (**thokar**) being 2 feet 3½ inches. The openings left in the upper part of this oven, when the pan has been placed on it, are filled up with mud from inside and outside as in the case of the **parchha,** and plastered round inside, as well as outside, with moist well-kneaded clay, so as to form a mud ring similar to the **"got"** described above. This vessel is capable of holding about 12 standard maunds of juice as it comes from the mill, and a corresponding quantity of boiled syrup. Experience has shown that the quantity of the syrup shared by this pan under the Rohelkhand system has to stay longer in the vessel than is desirable, with the result that both caramelisation and inversion are favoured and are very easily perceptible in the latter stages of the boiling. It having been found more advantageous to concentrate a thinner syrup or even clarified juice in small quantities to the requisite **rab** consistency, with the utmost possible rapidity, than to allow the juice in large quantities to

pass slowly through the various intermediate stages of thickening, and stay longer in those stages, it was very desirable that the size of this pan should be materially altered so as to hold a smaller quantity of the syrup which would concentrate more quickly to a thick consistency. In the improved arrangement (vide Illustration V) now recommended to the notice of the Indian industry, the vessel adopted in place of the **phadka** is exactly of the same shape and dimensions as the **parchha** and the name **"Manjha"** has been given to the new pan.

By thus substituting another **parchha** (the **manjha**) for the larger size **phadka** of the Rohelkhand **bel,** the concentration of the syrup into the final **rab** consistency is far more rapid, and the caramelisation is so controllable as to be kept at its minimum limits. Although the quantity so concentrated is admittedly somewhat less in the long run, yet the quality of the resulting **rab** is so superior with reference to its colour and sucrose content, as to amply justify the recommended modification in the size of the pan. In the Rohelkhand **bel,** the temperature of the boiling syrup in the **phadka** under the local atmospheric pressure never exceeds 99°C; usually it is lower. In the improved system the contents of the corresponding pan indicate a distinctly higher temperature which accelerates concentration. It will be seen thus, that while the final consistency is attained in only one pan, the **parchha,** in the indigenous system at one time, the same process practically goes on in two pans of equal dimensions concurrently in the improved arrangement. It will also be seen that, because the **phadka** has to be necessarily placed in a slanting position on the oven in the Rohelkhand system, it is impossible for the pan to hold a liquid up to the brim, the surface of the boiling syrup inside remaining as is indicated by dotted lines in Illustration (IV) As a result of the situation, as soon as the surface of the liquid sinks by concentration below the **"got"** (vide Illustration IV) to the lower portion of the pan in immediate contact with the current of heat below, (and this occurs very frequently during the boiling process), the southern corner of the pan which receives the largest amount of heat gets over-heated, and as there is no mud plaster there, to offer protection, the inevitable charring of the sugar becomes immediately perceptible, the inner surface of the pan in the southern corner becoming dark on account of deposit of carbon on its surface. The caramel deposit mixes up, though in small quantities and slowly but constantly, with the boiling mass which rises up in bubbles and goes down again with the variation in the temperature. This caramelisation affects the quality and colour of the **rab** as well as the colour of the resulting crystals on the one hand, and favours inversion on the other. The same remarks apply with greater force in the Rohelkhand system to the larger vessels of similar shape placed higher up holding larger quantities of

boiling material and retaining the same in them for longer periods. This feature of the Indian **bel**-system of boiling is open to the most serious objection and forms the root of all the evil and mischief so far as the main object of **rab** manufacture, namely, production from it of white sugar, is concerned.

In the improved arrangement (vide Illustration V) the disadvantage in the situation of the **phadka** has been overcome by replacing that pan with one **manjha** of the shape and size of the **parchha** which is capable of being fixed in an even instead of a slanting position, and thus of enabling the liquid inside to boil up to the brim without or with the minimum of charring.

In the Rohelkhand **phadka,** (vide Illustration IV), the charring is very considerable because it contains more than double of the quantity of boiling syrup contained in the **parchha** and cannot empty itself until the contents of the **parchha** have been discharged, while caramelisation in it is going on all the time. Again, it takes some little time to ladle out by hand the contents of the **phadka** into the **parchha,** when it is empty and ready to receive the same. The boiler cannot simultaneously transfer the liquid from the pan higher up into the **phadka,** and the result is, that part of the sugar in the latter inevitably gets burnt and mixed up with the liquid subsequently supplied to the **phadka** from the upper vessel.

The third or the middle pan of the indigenous system is known as the **Khaula** (from **"Khaulna"** to boil violently) or **'Phula'** (from **'Phulna'** to swell up), so called because the clarified juice received by it from the next higher pan begins to thicken into syrup in it as a result of boiling at a quicker rate. The diameter of this pan is about 5ft. 10 inches and the depth about 1ft. 9in. The full capacity of the pan is 25 Maunds of juice but on account of its slanting position it holds only about 20 Maunds in actual working. This vessel is subject to all the defects already described in case of the **Phadka.** In the improved arrangement (Illustration V), a radical change in the shape and size of this pan has been found essential. The bottom has been made flat instead of concave and the round wall perpendicular. Both have been constructed with galvanised sheet iron, the bottom being thicker than the wall. A brass cock, not shown in the illustration, has been inserted at the base in the northern part of the iron wall, which overlaps the round pan down below and saves the boiler the labour of ladling the syrup into the lower vessel. The diameter of the new pan is three feet three inches and the height 1ft. 6in. It has been ascertained by actual experiments that the amount of heat received in the oven below this vessel is incapable of boiling with due rapidity, a larger amount of juice than it can hold, so that this size has to be regarded as the standard for efficient boiling. Here, the liquid

boils with continuous violence at a temperature of 99°C against 98°C, which is about the average in the indigenous **Khaula.** The southern end of the flat-bottomed pan is the part receiving constantly the largest amount of heat. The result of this arrangement is that any impurities in the clarified juice it receives from the next higher pan, rise up perpendicularly to the surface of the boiling liquor at the southern end, and there they form a frothy stream which naturally flows like a continuous wave towards north. The impurities so removed by physical causes cannot find their way back towards south, owing to the resistance offered by the current coming from that direction. The impurities once removed, therefore, accumulate automatically and stay at the northern end of the pan which overlaps the lower vessel and gets practically no heat direct from its oven which could disturb the scum. The boiler finds it quite easy to remove the impurities at his convenience. In case of the **Khaula** of the Rohelkhand **bel** (Illustration IV) with a concave bottom, though this desirable object is partially secured, the achievement cannot be maintained right through the working day, for at the advanced stages of the boiling, the concave bottom gets so hot that the liquor inside begins to boil from the middle of the mass, instead of at the southern end of the pan, and the impurities thrown up get so mixed up with the liquor, that the boiler with all his assiduity and keenness finds it impossible to remove them completely by means of the **Pauna,** with the result that the impurities eventually form part of the **rab,** and later, of the sugar made by machining it.

The second pan of the Rohelkhand **bel** (Illustration IV) commencing from the southern corner is called **Nikhar** (from **'Nikharna'** to clarify) and forms the most important component of the set, because it is in this pan that defecation of the juice, forming the very basis of success in the subsequent operations, is carried out. It is larger in size than the sister pan lower down, being about 6ft. 4½in. in diameter, about 2ft. in depth and capable of boiling 25 maunds of raw juice. As a matter of fact when the last four pans have been charged fully with the respective quantities of juice required for them, a few tinfuls of juice are at the start poured into Ist. pan **'Hauz'** which is the largest in the set, the supply of juice coming subsequently from the mills being collected in that pan as it is delivered. Fire is then lit in the oven adjoining the **bilaiya,** and defecation of the juice is effected in the last three pans, the charge in the **parchha** being the first to get clarified. Defecation in the two pans higher up follows. At this stage the liquor in the last three pans is more than sufficient to carry on the boiling operation until the juice in the **Nikhar** has received the amount of heat sufficient to make the impurities rise up in the shape of scum with the help of the defecating agents employed, when clarification is brought about in the **Nikhar.** Hereafter the clarifying

process remains confined to this pan throughout the working period, the clarified liquor being transferred from one pan to the other to be converted into syrup and finally into **rab** in the **parchha.** The **Nikhar** has thus to play a highly important part in the operations. The clearer the liquor it supplies to the lower pan, the better will be the quality of the resulting massecuite.

Now it must be remembered that the current of fire becomes weaker and weaker as it travels from the oven through the channel upwards. The heat ordinarily received by the **Nikhar** in the Rohelkhand **bel** has been found by careful observations to be wanting in the intensity which is necessary not only to ensure quick clarification of the juice in the pan, but to keep the liquor boiling continuously after the clarification which is a desideratum for successful production of high class **rab.** What actually happens in practice is that, on account of the great bulk of the juice, the maximum rise possible in the temperature of the juice in the **Nikhar** pan, with the amount of heat available is insufficient to ensure complete clarification with any pretensions to rapidity. Indeed the rise is objectionably slow and the liquid never gets any hotter than at the boiling point, with the result that it boils only gently after clarification instead of boiling violently as is desirable. The boiler begins to remove the scum before it has all come to the surface, giving rise to conditions which interfere with complete elimination of the impurities by natural forces. The resulting liquor is therefore only imperfectly clarified. In a glass tumbler it looks hazy instead of transparent which it should do, and is found to contain flocculence composed of small particles of impurities which tend to deteriorate the quality of the finished product. So long as these conditions are allowed to exist, it would be idle to expect the best results. Perfect clarification being the governing factor, in successful sugar-boiling, it is essential to alter not only the shape, but also the size of this vessel so as to ensure more rapid and complete clarification of the liquor and violent continuous boiling of it, after that operation is over.

With this object in view, the size of the **Nikhar** pan in the improved **bel,** (Illustration V), has been shortened as compared with that of the **khaula.** Its diameter is only 2 feet and 10 inches although the depth is the same as that of the **Khaula,** and it holds about 6 to 7 maunds of juice in actual working. Experience has shown that in a pan of these dimensions, the defecating process takes shorter time than in the indigenous **bel** system and what is more important, the liquor when clarified is transparent and singularly free from floating particles of undesirable impurities. It has been found impracticable to provide this pan with a brass cock similar to the **Khaula,** the reason being that if a brass cock is provided, the pan will have to be placed at such a height above

the fire channel, that it would only receive heat insufficient to enable it to serve the very objects which have rendered the modification imperative. The liquor from this pan must therefore be ladled down. Another advantage of using a flat-bottomed pan smaller than the **Khaula,** as the main clarifying pan, is that it furnishes in quick succession the instalments of the clarified liquor necessary to always keep the hotter **Khaula** boiling at its full capacity. The liquor is thus converted into syrup sooner than if it were to stay longer in the **Nikhar.** After clarification too, the liquor in the **Nikhar** keeps boiling with great force instead of simmering as in the Rohelkhand **bel,** which materially hinders elimination of impurities. For the same reasons the raw juice in the upper pan **"Hauz"** II of the improved **bel** which receives less heat, has an earlier chance of finding its way into the hotter vessel **Nikhar** than it would, if the latter were of a larger size. The two aims of the various improvements hitherto described are quick and efficient clarification of the juice and the maximum rapid concentration of the liquor possible with the thermal units available.

The first pan of the Rohelkhand **bel,** (vide Illustration IV), is a huge vessel about 8 feet in diameter at the top and having a depth of about 2½ feet, being capable of holding about 50 maunds of juice. It is used merely as a receptacle for collecting and warming the juice as the latter is brought from the bullock-power crushing mills, by means of the **mashk** employed by the **Behishti** (juice-carrier). If a power-crusher is used, the juice may be carried through an iron channel connecting the pan with the crusher. The earthen receptacle (**mata** or **nand**) used ordinarily in the cane-crushing yards of Rohelkhand is very unsuitable for the purpose. On account of its large size it takes too long to fill up, so that fermentative changes begin in the juice before it can reach the **Hauz** pan, as a result of the action of bacteria being harboured by the porous earthen vessel. In some places the **Matas** have been replaced by kerosene tins for facility of transport and the practice should with advantage be universally adopted. If tins are used, the supply to this pan will be almost continuous and there will be no fermentation, but there will undoubtedly be charring, in course of the filling until the surface of the juice has risen above the point where the **"Got"** (plaster-ring) prevents that occurrence, and again when the surface sinks below that point. This is the most serious disadvantage in using the huge vessel of the size standardised for the **bel** in common use in Rohelkhand. Another drawback which handicaps the manufacturer under this system is that on account of the great bulk of the juice in the pan, the temperature variations are for several hours after the start within the range of degrees of hotness favourable to inversion. Usually the temperature does not reach 75°C, when inversion so far as

it is due to the action of enzymes is believed to stop. That temperature is not exceeded until only a few tinfuls of juice are left in the pan towards the end of the operations, but then the charring is at its highest.

To overcome these defects the size of the corresponding pan **Hauz** II has been greatly reduced too in the new arrangement, (Illustration V). The bottom has been made flat so that while there is even a small quantity of juice in the pan sufficient to cover the bottom surface, there should be no charring, while inversion is minimised as a result of the high temperature which the contents of the pan attain within a reasonable time. After about three hours of working it rises to the boiling point, so that clarification of the juice in **Hauz** II can be conveniently effected by the usual process and is as perfect as in the **Nikhar.** The dimensions of the two improved **Hauz** pans are about the same as those of the **Nikhar.** In the improved arrangement (Illustration V) an extra pan (**Hauz I**) of the same size as the **Nikhar** has been provided and the new system thus consists of six pans altogether instead of five composing the indigenous set.* The heat at the southern end of the improved furnace is sufficiently intense, 3 to 4 hours after the start, to render effective clarification possible in this extra pan too. Thus the juice instead of remaining warm as is usually the case in the **Hauz** of the indigenous system, would be found to attain the boiling temperature within a reasonable time and inversion would thus be minimised. If the **Nikhar** has to be emptied before juice in **Hauz** I or **Hauz** II of the improved system has been clarified, the contents of either of the said two pans should be transferred at once to the **Nikhar** to undergo the clarifying process, and their place taken by fresh juice from the mill. It will thus be seen, that when the operations are fairly advanced, about 5 or at least 4 out of the six pans maintain the boiling temperature or a higher one, and this is the greatest advantage of the new system. Ordinarily 8 bullock-mills working regularly under normal conditions will suffice to keep pace with the new **bel,** but if at any stage it is found that the supply is greater than the capacity of the new **bel,** it will be well to keep a spare pan of a suitable size close by, for collecting the juice in excess. It is not claimed that the boiling capacity of the improved set of pans is equal to that of the **largest** Rohelkhand **bel,** but the former is capable of yielding the same daily output as the manufacturer gets from a **bel** of average Rohelkhand size in ordinary working. In trials hitherto held at Bhopal the improved **bel** has been found to cope with 90 to 100 maunds of juice which may be less than the quantity worked up by the largest **bel** of the old type. It is however claimed with absolute confidence based on practical experience,

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*Recently a system of 7 pans has been successfully tried at Bhopal and found to boil about 130 Standard Maunds of juice in a working day, the extra (7th) pan being placed behind **Hauz** I.

that the **rab** produced by the improved **bel,** provided the cane used was of average richness, free from disease, and ripe, will yield in the centrifugal about 30 to 40 per cent more of white first sugar than the **rab** obtained from similar cane through the Rohelkhand **bel,** the quantity and the colour of the sugar being incomparably superior in the former case. The first molasses in the same case will also, when re-boiled, yield second sugar in greater quantity (28 to 38 p.c. of the weight of second **rab**) than in the latter case, without causing undue strain on the centrifugal machine on the score of viscosity, and the product will be as white and powdery as the Benares **chini** instead of a dark, yellow or brown sticky material, as is obtained now in the Rohelkhand factories working with centrifugals. Moreover, the second molasses will be of a bright orange colour instead of dark brown, capable of finding a more ready sale and of re-conversion into a lower grade massecuite to yield a third crop of pale sugar, should that operation be considered desirable; the third **rab** yielding 20 p.c. of its weight as third sugar.

To sum up, the factors constituting the main defects of the Rohelkhand **bel** are, (1) the hugeness of the iron vessels incapable of being properly cleaned every day and difficult to transport, (2) the formation in them of undesirable iron compounds as a result of the chemical action of organic acids present in the juices, (3) the injurious effect of these compounds on the colour of the sugar crystals (4) the detention of the large bulks of the juice, the liquor, and the syrups in the vessels for prolonged periods at temperatures not sufficiently high, (5) the unavoidable boiling of the juice from the centre of the **Nikhar** pan instead of from the southern end resulting in failure of the manipulator to achieve perfection in the clarifying process, and (6) the continuous and inevitable caramelisation and inversion of sugar in every one of the pans specially in the latter stages of the boiling operations, when the intensity of the heat exercises a literally ruinous effect on the reduced bulks of the various liquids. In the improved **bel** attempt has been made to entirely overcome the said defects except for the little charring which in theory must take place in all open pan rapid-boiling systems, in the last pan, at the time of removal of the finished material, but this is in practice minimised by stopping the feeding of the furnace for a couple of minutes before the mass is ready, and by quick transference of the same by the skilled boiler into the adjoining earthen **nand,** and of fresh syrup from the **Manjha** into the **parchha,** while the former can immediately be replenished without inconvenience to the boiler by opening the brass-cock of the **khaula.**

The quality of the **rab** would be very materially improved if the liquid is discharged from the **parchha** at a temperature of about

104-105°C and then boiled separately in an "auxiliary **bel**" consisting of 3 pans, placed on a furnace having 3 ovens, constructed on the lines indicated in the chapter dealing with manufacture of **gur** on commercial scale. **Rab** so boiled is almost entirely free from charred sugar, because the **parchha** is removed from its oven with the hands as soon as the desired consistency is attained in order to discharge its contents for the "airing" process and there is no chance thus for caramelisation to take place. Such **rab** always yields beautifully white sugar in a high-speed centrifugal.

To start work in the improved arrangement as soon as the **pardah** arch has been bricked, the **parchha** and the **manjha** should each be charged with about 1½ tinfuls of fresh juice, the **Khaula** with about 8 tinfuls and the remaining pans with about 4 or 5 tinfuls each, unless juice is available in sufficient quantity to fill them all up to the extent of their full capacity. Care must be taken, however, to begin the boiling as quickly as possible, so that fermentation may not set in. The boiler should be careful to keep one or two tinfuls of clean cold water close at hand and one or two tinfuls of the defecating agent (**Bhindi, Deula or Semal,** whatever it may be) besides a **nand** of saturated lime-water and a boiled solution of **sajji** in a tin or earthen jar. Fire should then be applied and feeding through the **bilaiya** continued zealously (by even two feeders if necessary) so as to sufficiently heat the furnace within an hour or so. In 10 to 15 minutes the juice in the **parchha** should attain the boiling temperature when clarification should be done by adding the mucilaginous defecants, ebullition being controlled by addition of cold water when necessary. By the time the defecation is complete, and sometimes a little earlier, the juice in the **manjha** will be ready to undergo the clarifying process, which should at once be taken in hand. It very often happens that the clarified liquor in both of these pans shows a tendency to overflow. Should it be found difficult to check it by addition of cold water, part of the clear liquor should be taken out into a tin in order to replenish the two pans at intervals and to keep them boiling until the juice in the **khaula** has been clarified. Saturated lime water should be used sparingly as soon as the liquor becomes transparent, in each case **sajji** solution being put in before liming. In order to save fuel, labour, and time, and therefore to avoid as far as possible any avoidable increase in the volume of the liquid requiring concentration, the Rohelkhand boiler is averse to introducing the mucilaginous liquid defecant in quantities sufficient to ensure complete liberation of the separable nitrogenous bodies contained in the juice, with the result that the liquor obtained by him in the **khaula** or **nikhar** is singularly wanting in clearness and is loaded with finer particles of impurities in suspension. This procedure should be looked upon as bad economy. Not less than a tinful of the liquid defecant has been found to be the quantity adequate for

clarifying 8 tinfuls of juice. Care must also be taken to introduce the mucilaginous liquid after the temperature of the juice has risen to the boiling point and the cracking of the scum layer on the top has well advanced, and not before. With fall in the temperature, which follows, any separable particles still contained in the juice are set free and ascend to the top, whence they are easily removed with the thick layer of the scum. If it is found that the waves of impurities do not continually travel from south to north, it should be concluded that the fault lies in construction of the furnace, which must be remedied when the furnace is cooled down, by removing the **khaula** or the **nikhar** pan, as the case may be, from the furnace and so rectifying dimensions of the oven below that it may receive the highest degree of heat at the southern end, and the boiling must not be allowed to originate except in that part of the pan. Too much emphasis cannot be laid on the necessity of faithfully observing this important rule, as neglect to do so would only result in bad clarification and defects in the quality of the massecuite.

When a fairly clear liquor has been obtained, the **sajji** water should be more freely used than is the rule in Rohelkhand. At the time of using this agent, however, the fire must be lowered by reducing the rate of feeding at the **bilaiya,** otherwise the violent ebullition which follows its introduction into the pan may be too severe, causing an uncontrollable overflow. Besides, the chemical and physical changes due to the agent take place better at a temperature below the boiling point. It is well known in Rohelkhand that the use of **sajji** beyond a certain limit darkens the colour of the resulting **rab** and therefore affects adversely the market price of it. The Rohelkhand boiler is therefore exceedingly unwilling to use it except sparingly. He is ignorant, however, of the fact that although the excess of **sajji** may darken the colour of the **rab,** the use of it in larger quantities than is so far believed to be permissible, very remarkably favours formation of a heavier crop of strong crystals in the **rab** while cooling, and the dark or darkish **rab** obtained yields a perceptibly higher percentage of normally white **khand** in the centrifugal. The author has seen on several occasions that the **rab** nearly as dark as the Indian bazar ink, obtained as a result of use in excess of **sajji,** has given highly satisfactory results both as regards the quality and the quantity of the sugar (both first and second) in the machine. Whether the **Sewar** weed will effectively bleach such dark coloured **rab** in the **khanchi** system, the author is unable to say, having never had an opportunity of trying it in the **khanchi.** But it can safely be recommended that where manufacture of **rab** is intended for treatment in the centrifugal, **sajji** water should be used in quantities two to three times, as large as employed now in Rohelkhand, and a highly rich **rab,** conspicuously free from viscosity thus obtained,

Indeed it is with such specimens of **rab** that between 50 and 58 per cent of white sugar was obtained on curing. The colour evil can be removed at least partially by subsequent introduction of small quantities of sodium hydrosulphite in the liquor (after its treatment with lime-water which should follow the use of **sajji**) until it is found that the chemical does not exercise any further bleaching action, The said chemical may be introduced perhaps with greater advantage in the **parchha** three or four minutes before the required consistency of the **rab** is achieved. In manipulating the juice of the red canes, usually rich in colouring matters, the use of the hydrosulphite is strongly recommended as it certainly improves the colour of the **rab** and there are reasons to think that it also increases the amount of crystals though it cannot be said definitely that the latter is invariably the result. If however the object is to produce white sugar having large and brilliant crystals the use of **sajji** in excess should be avoided and that of lime-water entirely dispensed with.

As soon as the clarification and sulphitation with the **Sajji** are over, the temperature of the liquor should be raised again by the continuous feeding of the furnace and a boiling temperature maintained till the contents of the pan are transferred to the lower vessel. It must be carefully borne in mind that the use of the hydrosulphite in excess results in the production of yellow or pale sugar. It is therefore important to use it very sparingly.

These remarks apply equally to the **Khaula** or **Nikhar** whichever vessel may be used for the time being for carrying out the clarification process. The **Khaula** usually serves the purposes of a clarifier in the first charge, thereafter the **Nikhar** is the vessel in which the juice undergoes clarification.

Lastly, the main purpose of the first pan (**Hauz** I) is to receive from time to time the juice transported from the crushing yard and to heat it to the varying degrees of temperature possible at different hours in the natural course. As has been stated before, if there is at any time more juice at hand than this pan is able to hold, the excess should remain temporarily in kerosene tins or collected in a spare pan near by. When the boiling operations are well advanced, the juice in **Hauz** I becomes quite hot, and attains the high temperature necessary for normal clarification. The rising scum should, when the top layer becomes fairly thick be gently removed and transferred to the filter. As soon as **Hauz** II is empty, the partially clarified juice should be ladled into the last named pan and its place taken in **Hauz** I by juice fresh from the mill.

In Rohelkhand it is customary to pot the **rab** in earthen jars known as **kalsis.** The author has however used kerosene tins and found them more advantageous. The earthen jar has to be broken in order to take the **rab** out for curing. Minute particles of the broken jar usually get mixed with the **rab** and can never be separated from the resulting sugar. This feature affects the quality of the sugar. If tins are used for storing the **rab** this particular disadvantage is avoided and the same vessel can be used several times for potting. **Rab** may be stored perfectly well in large iron crystallisers or masonry tanks.

Before the final product is potted and as soon as it has been discharged from the **parchha** into the **nand** (earthen receptacle) it should be "aired" i.e. subjected to the process known in Rohelkhand as **osa dena.** It consists in stirring the rab with a **"dori"** (a cup to which a handle is attached) lifting it and pouring it back into the **nand** so as to bring the mass frequently into contact with cool air. The operation is repeated for 10 to 12 minutes and is meant to bring about crystallisation in motion.

There is no difference whatever between the process of making **rab** and that for producing superior **gur,** except that for the preparation of **rab** the degree of syrup concentration is lower. Thus, while for **gur** the syrup may be boiled to a temperature of from 117°C to 120°C, **rab** is ready when the temperature ranges from 110°C to 115°C, and the **rab** found most generally suitable for the centrifugal machine is discharged at about 112°C. The sugar trade has classified specimens of **rab** generally produced in Upper India into recognised grades fixed in accordance with the consistency. These grades are:—

(1) **Sharbati.** The consistency in this case is thin, the massecuite being ladled out of the **parchha** at a temperature of about 110°C. On storage the molasses generally separates naturally and rises up to the top of the earthen pot or kerosene tin (whichever may be used as crystalliser, leaving a mass of crystals beneath. The crystals of this grade are usually fairly large, strong and well-formed. and separate very easily whether the **rab** is treated in a centrifugal or in the **adda** (the pile of woollen bags through which the molasses is squeezed out by pressure). The percentage of **rab** on the juice is high, but the yield of first sugar which is generally of a very superior quality is not high. The first molasses is consequently rich and yields a high percentage of second white sugar when re-boiled into **rab** which is machined after completion of crystallisation.

(2) **Mota-Dora.** ("thick thread"). The final consistency in this case is attained at a slightly higher temperature, about 111°C. Here too the grains are fairly large from the Indian manufacturer's point of view. The molasses accumulates at the top leaving the crop of crystals underneath and separates easily in the machine. The sugar made from this grade is composed of stronger and larger crystals than the average Indian **khand** and does not form lumps on storage. The yield of the sugar is not much above that of the **Sharbati** and the first molasses produces second **rab** which is not viscous and gives a good yield of white sugar.

(3) **Jau-Khasi.** In this case the consistency is of medium degree and the name is applied because this **rab** generally contracts on cooling, so that the surface of the liquid goes down (**khasna**) about the length of the size of a grain of barley (**Jau**). The charge is struck at a temperature of 112°C. The crystals are of medium strength and size, and this grade is admirably suitable for the centrifugal, while it is also the best for treatment in the **khanchi** system of manufacture of **khand** (vide chapter IX of the "Sugar Industry of the U.P.").

(4) **Mohr-Jam.** (So solid as to be capable of bearing an impression with the **mohr** or seal). This grade is more close-boiled than those mentioned above, the boiled mass being struck at a temperature of about 113°C. or 114°C. **Rab** of this grade does not demand much airing and crystallises quickly. Usually there should be no molasses at the top of the pot, but if stored for several days a certain quantity may be found in the middle of the pot as a result of natural separation. The crystals are finer than in the preceding grades and the **rab** has to be mixed freely after passing through the pug-mill or being "broken" otherwise, with molasses obtained in a previous machining operation before being capable of treatment in the centrifugal. The yield of white sugar in the case of this grade is, speaking generally, about the highest, though the crystals are fine and the charge in the centrifugal when revolving generally requires an extra washing in order that the resulting sugar may be of good white colour. The first molasses is not so rich in sucrose as in the former cases, with the result that the

second massecuite made from it is viscous and takes more time to cure while the second sugar made is not so white as one would wish.

(5) **Khunta-thonk.** This **rab** is the thickest made, the strike being taken at a temperature of about 115°C and the name signifies that if a peg (**khunta**) is to be driven into the **rab,** it would need, on account of the hardness, to be hammered in (**thonk**). In this case, as would be expected, the percentage of **rab** on the juice is lower but the recovery of the sugar from the **rab** is high, though undoubtedly at the expense of quality.

It is best therefore to aim at the production of the **Jau-khasi** type in ordinary working for purposes of **khand** manufacture and of **Mota-Dora** for that of sugar having larger crystals. **Mohr-Jam** and **khunta-thonk** are types not suitable for sugar production because of the inferior quality of sugar they yield.

The boiling plants recommended in Chapter X for **gur**-making will answer equally well for manufacture of superior **rab** on a small cottage industry scale, but the size of the concentrator as well as of the clarifier may be made larger, if there is sufficient material to work upon. Some of these sizes have been actually tested in Bhopal and found quite suitable to the requirements of open-pan boiling on a cottage industry scale. Concentration was rapid with the minimum of charring. The quality of **rab** turned out by these small plants is remarkably good and has uniformly high sucrose content, which varies from 71.17 to 83 per cent according to the quality and variety of the canes, the exotic and seedling canes usually yielding particularly rich specimens.

Where there are a number of mills working together in the boiling yard, or there is power-crusher for extraction of the juice with the object of working on a larger scale, it would be uneconomic to rely on these small plants; then the improved **bel** described before should be installed.

The cost of boiling rab.

This differs in parts of Rohelkhand with the quantity of juice available during the working day, the size of the pans, the efficiency of the furnace, the degree of dryness of the fuel (a highly important factor), the assiduity and skill of the boilers, the weather conditions, the local customs regarding payment of perquisites and other circumstances. The pride with which the Rohelkhand boiler and his methods are generally accredited, lies more in the quantity rather than the quality of the output. The larger the size of the pans and the day's output the more defective the quality usually is for reasons already stated before. As a matter of fact it is the

average and not the largest **bel** that is commonly employed in the industry and although the cost of boiling is less in exceptional cases, yet the quality of the resulting product is never comparable in respect of the yield of sugar and colour with that produced under the improved Bhopal system.

In the sub-joined table are compared the actual figures of three **bels** working under different conditions on the lines of the indigenous Rohelkhand system with those of the new improved **bel** elaborated in Bhopal.

Different heads of the daily cost of working.	Particulars of the **bels** and the cost under each item.											
	A typical average **bel** working in Shahjahanpur Distt.			A typical **bel** of the largest size working in Shahjahanpur district, power crusher and pump being used.			A large **bel** attached to a power-crusher working in Hardoi (Oudh).			The improved Bhopal **bel.**		
	Rs.	a.	p.	Rs.	a.	p.	Rs.	a.	p.	Rs.	a.	p.
Munshi (the Accountant) ..	0	10	6	0	10	6	Nil			0	8	0
Expert boiler and his assistant	1	4	0	1	8	0	1	10	0	1	8	0
Behishti for carrying the juice and water or ordinary labourers employed for doing the same work ..	0	4	0	Nil			0	4	0	0	6	0
Jhonkas for firing the furnace, carrying bagasse clearing pans etc.	1	4	0	1	8	0	1	3	0	1	8	0
Darogha (the executive officer)	0	6	6	0	6	6	0	5	0	0	6	0
Sajji	0	2	6	0	2	0	0	1	0	0	2	0
Lime	Nil			Nil			Nil			0	0	3
Castor Seed	0	1	6	0	3	0	0	4	0	0	2	0
Sodium Hydrosulphite ..	Nil			Nil			Nil			0	1	0
Deola or Bhindi (Hibiscus Ficulnus or Esculentus) Falsa (Gravia Asiatica) or Semal (Bombax Malabaricus) ..	0	12	0	0	12	0	0	2	0	0	1	0

Different heads of the daily cost of working	Particulars of the **bels** and the cost under each item.			
	A typical average **bel** working in Shahjahanpur Distt.	A typical **bel** of the largest size working in Shahjahanpur district, power crusher and pump being used.	A large **bel** attached to a power crusher in Hardoi (Oudh).	The improved Bhopal **bel.**
	Rs. a. p.	Rs. a. p	Rs. a. p.	Rs. a. p.
Kerosene oil for lamp ..	0 3 0	0 2 0	0 0 9	0 1 0
Cloth strainers, Scum-baskets with stands	0 1 3	0 1 3	0 1 3	0 1 3
Kalsis (earthen jars) or tins	1 0 0	2 1 0	1 4 0	0 12 0
Perquisites (rab, juice and Inams)	1 0 0	Nil	Nil	Nil
Hire of the pans	0 10 8	Nil	Nil	Nil
Incidence of the cost of fire-wood	0 15 1	Nil	1 0 0	Nil
,, furnace	0 7 0	Nil	Nil	Nil
Depreciation on pans ..	Nil	0 5 0	0 5 0	0 5 3
Depreciation on buildings	Nil	0 11 0	0 11 0	0 1 0
Chaukidar	Nil	Nil	0 3 0	0 6 0
Total ..	9 2 0	8 6 3	7 6 0	6 4 9
Total weight of juice boiled (Standard maunds)	75	150	140	90
Total weight of **rab** obtained (Standard maunds) ..	14	30	25	19
	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Cost per maund of juice boiled	0 2 0	0 0 11	0 0 10	0 1 1
Cost per maund of **rab** obtained	0 10 5	0 4 6	0 4 9	0 5 3

It will be seen that although the new **bel** is capable of boiling during the working day nearly 2/3rds of the maximum quantity of juice said to be workable in the largest Rohelkhand **bel,** the former will, when worked at its normal capacity give, with a distinctly smaller cost, a larger output than the average **bel** of Rohelkhand and the **rab** will be much superior in quality.

CHAPTER XII.

Production of White Sugar.

Manufacture of First Sugar.

The simplest and cheapest method of manufacturing the indigenous white sugar (**khand**) known as the **"Khanchi"** system, has been practised at its best in Rohelkhand for centuries, **rab** made from the cane juice being used as the material from which to extract the sugar. The only other method for obtaining white sugar (**chini**) by indigenous processes is by refining **gur;** the **gur** is first converted into a form of massecuite by boiling with water, the syrup being clarified with milk and other agents to remove the impurities. This process is practised mainly in the Eastern Districts of the United Provinces and in Bihar. Both the methods are highly wasteful, the latter more so than the former, because the **gur** ordinarily produced in those Provinces is usually full of impurities difficult to get rid of by simple methods, and contains a high percentage of glucose owing to inversion caused by the defective methods of boiling. In both cases the molasses or **shira** has to be separated from the sugar crystals by pressing the **rab** in woollen or coarse cloth bags either by the feet or by heavy weights or by simple drainage through a hole made at the bottom of the earthen vessel containing the final product; the molasses exudes slowly and is run off into receptacles provided for the purpose, where inversion and fermentation of the molasses continue. The molasses cannot be sold immediately, nor is it good enough to be re-boiled into a second **gur** or **rab.** In the case of manufacture of **khand,** the dark brown crystals removed from the bags and known at this stage as **"potli",** are stacked in the refinery to a depth of about three feet on bamboos covered with reeds. The **Sewar** weed **Vallisneria Spiralis** or **Octandra,** famous for its mysterious property of whitening sugar crystals is spread over the **rab.** When the bleaching action ceases, the bleached layer of sugar is scraped off, pressed under the feet in the sun which exercises a further bleaching action and makes the white crystals uniform. Each successive layer of sugar so scraped and treated is lower in quality than the one obtained before and commands a lower price in the market. This class of sugar is graded and known in the trade as the **phul,** the whitest sugar, the **adhauta,** which is pale in colour and the **tarauncha,** which is still inferior.

The processes described are necessarily very slow, and hence the cost of labour is high, while the output of the white sugar **"khand,"** the sugar made from **rab,** is about 4 per cent of the cane employed. The yield of **"chini,"** the white sugar, made by refining **gur** is only about 30 to 33 per cent on the weight of the **gur** which is equivalent to 3 per cent or a little more on the weight of the original cane used for producing the **gur.**

The wastefulness of the indigenous processes led to a gradual and ultimately to a serious decline in the native sugar industry as it was naturally bound to do. When towards the end of the last century the Indian market became flooded with the beet root white sugar of Europe, particularly Germany and Austria, the attention of the Government of the United Provinces which grow more than half the total quantity of cane produced in India and in which Provinces the most important **Khand** and **Chini** producing centres were situated, was directed naturally to the necessity of adopting measures likely to prove beneficial to the interests of the old-fashioned manufacturers. An attempt was made by the Agricultural Department of the U. P. to work out improvements for the manufacture, stage by stage, and yet keep the operations simple enough to be readily adopted. The firm who introduced the iron cane-crushing mill which has now almost completely replaced the old wooden and stone mills (**Kolhus**), namely Messrs Thomson and Myln of Behea, helped this development by bringing out from England a hand-power centrifugal to remove the molasses from the **rab** and so produce the dark brown **"potli"** more easily. The general idea then was that the **"potli"** should be sold to refineries working on modern lines with imported machinery. The **potli** so obtained was known as "Turbine sugar" and in experiments with one of these centrifugals carried out by the Agricultural Department of the U. P., it was found that the sugar of the finest pale colour was secured from Rohelkhand **rab,** when the **rab** was of good quality and the machine was run at full speed, which was about 600 revolutions per minute. Till that time no local manufacturer had thought that white sugar of any grade could be produced by a centrifugal, the general belief being that bone-charcoal treatment of the syrup was necessary before boiling, and then alone could a centrifugal be successfully employed for the production of white sugar. However, the experiments made in the U. P. Agricultural Department in 1902 suggested that a remarkable improvement in the colour of the **potli** might result, if a high speed centrifugal were employed and superior **rab** worked with it. The requirements were explained in full details to Messrs Thomas Broadbent & Sons, England, who constructed and furnished the hand-power under-driven centrifugal of 18" diameter known as the "Handelox" designed to run at 1800 revolutions per minute. Persistent trials with this machine confirmed the view that when the **rab** had been properly and carefully prepared and the charge washed in the centrifugal, the resulting sugar was quite white, always uniform in quality and the percentage of outturn was distinctly higher than that obtained with any indigenous process; also that the use of the **Sewar** weed could be totally dispensed with, which meant considerable saving of time and expense, as compared with the **Khanchi** system. Subsequently Messrs Thomas Broadbent & Sons

sent out a top-driven centrifugal of the Weston Type which ran at the same speed with appreciably less strain on the labourers but did not yield as fine a quality of sugar as did the "Handelox." While the Khandsaris of Rohelkhand made no efforts to improve the boiling of **rab,** they hastened to adopt the easy-running centrifugal of the Weston Type, in order to do away with the intermediate process of straining the **potli** in woollen bags. There are dozens and dozens of these hand machines running in Rohelkhand, but whole of the sugar produced is not quite white, and cannot be until their system of boiling the rab (the **bel** system) is materially altered. Ultramarine was used in Shahjahanpur and other centres to disguise the colour of the sugar to a certain extent, but, speaking generally, the quality of the machine-sugar is now distinctly inferior to that of the **Khanchi** sugar and fetches a comparatively low price. Some of the Rohelkhand manufacturers use the centrifugal only for the production of **potli** to be treated afterwards with "Sewar" and thus save the expenditure involved in producing the **potli** under the old method.

Later still, Messrs Thomas Broadbent & Sons introduced into the United Provinces, a steam-power centrifugal of 30″ diameter, combined with an engine and boiler, and a number of these machines are use in parts of Rohelkhand. The Indian manufacturer, a shrewd business man, has seen fit to adopt these machines and has used them for many years. This is evidence of the fact that it has paid him to do so, and it is now unreservedly admitted by the Indian manufacturer that the use of the machine yields more sugar in much shorter time and with less expense. This is the history of the events which led to the introduction of the centrifugal into the native sugar industry. During the experiments made with the centrifugal machines in the Indian refineries in the Meerut Distt. it was discovered that the **rab** produced in the neighbourhood of the Meerut City from the local thin canes **Dhaur, Bori, Kinara,** etc was the poorest in the U. P. due to soil and climatic conditions and perhaps to excessive irrigation from canal water which is generally available in abundance. Here the yield of white sugar varied from 30 to 33 per cent of the **rab.** In the **gur**-producing tracts of Dhampur in the Bijnor District the **rab** was, as a result of the soil conditions, also poor in sucrose. In other parts of Bijnor and in the Districts of Bareilly and Shahjahanpur and in the Rampur State, where **Dhaur, Pandaria, Rakhra, Kinara** and **Matna** are the principal favourite varieties of cane, the percentage of white sugar rose to about 35 or 36. In Rampur thousands of maunds of **rab** were boiled and machined annually for several years and the said figures of the outturn were uniformaly maintained. In the District of Lucknow in Malihabad working with the **Bharanga** cane the average outturn rose slightly, but the

highest average outturns, ranging from 36 to 40 per cent, of the **Rab**; were obtained further east in the Districts of Sultanpur, Benares, Allahabad and Jaunpur, the varieties cultivated at these places being **Kuswar, Sarauti, Reora and Mango.**

In the District of Allahabad an attempt was made, for the first time in 1908, to extract second sugar from the **rab** made out of the molasses, that is, the material remaining after removal of the first sugar. The experiment was watched carefully by the Agricultural Chemist to the Government of U. P. who found that assuming a yield from the cane of 65 per cent juice with a sucrose content of 15.12, one hundred parts of juice yielded 6.3 parts of first sugar and 2.7 parts of second sugar, or a total of 9.0 per cent. Now 65 parts of juice being equal to 100 parts of cane, 100 parts of juice represent 153 parts of cane. In other words 153 parts of cane yielded 9 parts of both forms of sugar, or 100, parts of cane produced :—

First sugar	4.11 parts.
Second sugar	1.76 parts.
Total ..	5.87 parts.

These figures when discussed by the Indian Sugar Committee (vide page 281 of their Report published in 1921) elicited the remark that the estimated extraction of 65 p.c. of juice was somewhat high and that 60 per cent should be regarded as the proper extraction. Basing their calculation on these data, the Committee came to the conclusion that the following were more reliable figures of outturn :—

First sugar	3.78	parts per	100 parts	of	cane.
Second sugar	1.62	do.	do.	do.	do.
Total	5.40	do.	do.	do.	do.

Assuming 100 parts of cane to represent 60 parts of juice or 10.8 parts of rab (18 per cent of the juice), the extraction of the first sugar from the rab calculates to 35 per cent. Deducting 3.78, the weight of the 1st sugar from 10.8, the total **rab**, the balance 7.02 represents the weight of molasses which on re-boiling would yield 5.79 of second **rab** (82.5 per cent of the molasses, a figure determined and confirmed by repeated trials). It was 5.79 of second **rab** that yielded 1.62 of second sugar or 27.9 per cent of its weight.

This was, as far as the author of these pages is aware, the *only* reliable chemical test carried out in order to determine the merits of the particular cane used in Allahabad, and of the process of

extracting sugar by means of a hand centrifugal, until Mr. Hulme the sugar specialist employed by the Government of the United Provinces, established the Nawabganj factory using an open pan boiling plant manufactured by Messrs Blair Campbell McLean, and a power driven centrifugal.*

Mr. Hulme aided by a competent sugar analyst worked for several years in Nawabganj. The results of his work in the years 1927-28 are discussed on pages 270 to 272 of the Indian Sugar Committee's Report. The Committee's remarks go to show that this plant could extract only 5.6 maunds of sugar (presumably both first and second sugars put together) per 100 maunds of cane or about the same quantity as has been obtained from the Rohelkhand **bel rab** or the Agricultural Department's boiling plant used in the Allahabad District. Because of serious loss of sugar in the open-pan boiling and waste in the course of the manufacture besides as unduly high cost of production, the Indian Sugar Committee recorded their disapproval of all such systems of producing white sugar and pointed out (vide page 268 of their Report) that 9.5 per cent of sugar from the cane was the outturn they "estimated as possible in a thoroughly efficient factory" worked on modern lines, as compared with from 4 to 5.6 per cent which until then seemed to be the best result achieved by open-pan boiling, the white sugar being separated from the **rab** either by a centrifugal or by the old methods. With the figures of the sugar outturn then before them, the conclusion of the Committee was inevitable, but while stating (vide page 274 of their Report Recommendation No. 2) that "in **gur** manufacture 34 per cent of the sucrose in the cane is lost or inverted compared with the result obtainable by an up-to-date sugar factory", they advocated concentration on conversion of the cane crops in general into **gur** as the only proper suggestion they could put forward under the circumstances. They furnished a plan of a new furnace designed to eliminate the defects existing in the furnace used by the manufacturers, suggested modifications in the small power-crusher then in use to ensure efficient extraction, and recommended that the Agricultural Engineering Department of each province (Recommendation 13 page 290 of their Report) should evolve a standard design for small power mills to crush one or two tons of cane per hour. They were doubtful whether **gur** manufacture in large factories was a commercial proposition, thus meaning to leave the manufacture of **gur** to the cultivator or to the small capitalists concerned in that business. At the same time the Committee considered the

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***The initial outlay on the plant was Rs. 67,840 (The Indian Sugar Committee's Report, page 271.)**

possibilities of manufacturing **muscovado** sugar or some other intermediate product, direct from cane, in small factories and of working this product up into white sugar in large up-to-date factories. The Committee declared it as their opinion that the practicability of the proposition was doubtful but that **"it should be investigated."**

No such investigation seems to have been made hitherto by any of the provincial departments of Agriculture or by any private individual or in any Indian State. Having been associated for many years with practical improvements in sugar-boiling and in the manufacture of various forms of sugar as Assistant Director of Agriculture in the United Provinces, the author of these pages as Director of Agriculture in Bhopal, utilised an opportunity to make the investigation suggested by the Indian Sugar Committee. This investigation which has now extended over three seasons namely 1924-25, 1925-26 and 1926-27 has proved beyond all doubt in course of protracted trials and most carefully conducted experiments, that the position as regards production of white sugar by open-pan boiling of **rab** followed by a centrifugal process has completely altered. This has been achieved by the introduction into Bhopal of canes very much richer in sucrose than the indigenous canes, the most successful ones being S. 48 of Shahjahanpur, P. O. J. 33 (known locally as Lakhapur), Co 221 and Co 213, two of the well known Coimbatore seedlings, and **Manjav** one of the famous canes of the Manjri Farm near Poona. For success it is also necessary to provide efficient crushing mills (bullock power was used) and to boil the juice with due rapidity and proper defecation in the system of pans already described. From Coimbatore seedlings acclimatised locally, the outturn of marketable white sugar (1st and 2nd put together) was more than double of that obtained by the Rohelkhand manufacturer with his local poor canes and the old **khanchi** system. Generally the results obtained by machining the **rab** when carefully prepared were so remarkable, that it was deemed proper to embody them in this publication for the purpose of general information. These experiments in the manufacture of white sugar were carried out with the utmost care at the Government Farm Bhopal, and the results are discussed below in three sections, the first dealing with the work done during 1924-25 and the second and third with that performed in the two following years, in order to show how success was achieved progressively in the research.

A. First Research Season (1924-25)

1. **White First Sugar.** The rainfall during the year being only 29 inches was distinctly below normal, but it was so well

distributed specially during August and September 1924, that the cane crop attained full growth and the development of the sucrose was normal. The sugar season therefore represented a fair average from the manufacturer's point of view. During this season the machine used was a self balancing 18" diameter under-driven centrifugal of the "Handelox" type so designed at the author's request by Messrs Thomas Broadbent & Sons as to be capable of being run at 1500 revolutions per minute either by hand power or by steam power at will. This type was indeed the first of its kind that ever came to India from Huddersfield. The bottom strap-pulley provided in the machine was however 1 foot in diameter (suitable for steam but hardly so for hand power working) instead of $9\frac{3}{4}$ inches the standard hand power size. For this reason the running of the machine generally caused undue strain on the labourers and it was found impossible to maintain the full intended speed of 1500 revolutions per minute throughout the spin. When the hand-power machine runs at irregular speed (sometimes slow and sometimes fast) the purging is not perfect and the colour of the sugar in the cage has to be improved by washing, which is done by injecting jets of warm or tepid water into the cage until the desired degree of whiteness is obtained. When the purging is not good by the spin, excess of water may be used but beyond a certain limit the process of washing causes undue loss of sucrose which passes into solution with the molasses into the receptacle placed to receive it. The centrifugal had to be worked necessarily under this disadvantage, it being imperative to make the requisite determination within the working season. The copper mesh fitted into the basket when the machine was delivered proved to be too fine, so it was replaced by the brass mesh of the local bazar as used for sifting wheat flour. This mesh however was so flimsy, that rather than damage it by close scraping, an ounce or two of sugar was sacrificed at each charge which was washed away and not collected. The object of these remarks, which might appear superfluous, is to make it clear to the reader that the determinations presently to be described were made with a centrifugal not in really good order and for which steam power was not available; consequently the outturns to be given below should, in fairness, be looked upon as really slightly less than they would have been, under the best conditions which might reasonably be hoped for. As was to be expected, the imported exotic canes and seedling varieties grown in Bhopal, just like the indigenous canes, gave a yield of white sugar which varied with each variety and each field.

The following table gives in some details the figures obtained in dealing with the **rab** of S.48, the red cane imported from the Government Farm Shahjahanpur :—

Date of machining the **rab**.	Date on which the **rab** was boiled.	Field No.	Variety of cane.	Quantity of **rab** machined.	Quantity of undried sugar obtained	Quantity of dried sugar	Percentage of undried sugar to machined **rab**	Percentage of dried sugar to machined **rab**
				lb. oz.	lb. oz.	lb. oz.		
28.2.25	1 pot boiled on 5.1.25 1 pot boiled on 6.1.25	6	S.48	73–0	34–12	33–2	47.60	45.89
1.3.25	2 pots boiled on 8.1.25 1 pot boiled on 15.1.25 1 pot boiled on 20.1.25	5	S.48	101–8	46–14	46–4	46.10	45.51
2.3.25	1 pot boiled on 5.1.25 1 pot boiled on 6.1.25 1 pot boiled on 7.1.25	6	Do.	92–3	43–6	41–14	47.01	45.38

3.3.25	1 pot boiled on 5.1.25	6	Do	24–13	12–1	11–4	48.62	45.36
5.3.25	1 pot boiled on 9.1.25 2 pots boiled on 15.1.25	5	Do	77–8	36–9	35–9½	47.17	45.92
7.3.25	1 pot boiled on 5.2.25	5	Do	15–8	7–12	7–8½	50.00	48.58
7.3.25	1 pot boiled on 6.2.25	5	Do	36–2	15–18	17–13	52.33	49.30
15.3.25	4 pots boiled on 3.3.25	12	Do	132–7	63–1½	61–5	48.26	46.29
5.4.25	1 pot boiled on 9.2.25	12	Do	31–0	15–14	15–6	51.20	49.59
5.4.25	1 pot boiled on 9.1.25 1 pot boiled on 19.2.25	6	Do	37–0	18–10	18–0	50.33	48.64
5.4.25	1 pot boiled on 21.2.25 2 pots boiled on 2.3.25	12	Do	71–8	34–10	34–4	48.39	47.93
	Total ...	...		692–9	332–7½	322–12	48.13	46.60

It must be stated that in the earlier experiments (the first five recorded above), only small charges of **rab** varying from 16 to 22 lbs. in weight were centrifuged. Latterly, it was discovered that the cage of the centrifugal was capable of holding quite conveniently, charges varying from 40 to 50 lbs., according to the quality of the **rab** and the last six results were obtained by using heavy charges. With these bigger charges not only was more work performed within a given time, but the yield of the resulting sugar was higher; further the heavier charges could stand adequate washing with the water syringe much better with less loss of sugar. Even with these rather erratic conditions of work the average outturn of dry sugar obtained from the **rab** of S. 48 amounted to 46.60 per cent. When the washing of small charges was excessive, the average yield of sugar fell to 41 per cent although **khand** of a remarkable degree of whiteness was obtained giving a polarisation of 97.92. When cane could not be crushed for 48 hours or so after cutting, and lay in the sun during the day, the yield of the first sugar fell to 37.20 per cent. This experience points to the conclusion that for successful working, it is imperative that not only should care be taken throughout the process to minimise losses of sucrose but also that the massecuite should be prepared from freshly cut cane.

P. O. J. 33 (locally known as Lakhapur) a much thicker cane than S. 48 very nearly approached the excellence of S. 48 with regard to its sugar yield, as would appear from the subjoined table:–

Date of machining the **rab.**	Date on which the **rab** was boiled.	Field No.	Variety of cane.	Quantity of **rab** machined.	Quantity of undried sugar obtained	Quantity of dried sugar.	Percentage of undried sugar to machined **rab.**	Percentage of dried sugar to machined **rab.**
				lb. oz.	lb. oz.	lb. oz.		
6.3.25	1 pot boiled on 16.12.24 1 pot boiled on 30.12.24	8	P.O.J. 33	77-10	33-10	33-2	43.29	42.65

30.3.25	1 pot boiled on 12.1.25	16	Do	35–15	18–2	17–8	50.41	48.74
30.3.25	1 pot boiled on 13.1.25	16	Do	30–0	15–2	14–12	50.33	49.16
5.4.25	1 pot boiled on 12.1.25 1 pot boiled on 13.1.25	16	Do	40–12	20–8	20–4	50.30	49.69
	Total			184–5	87–6	85–10	47.47	46.44

Unfortunately there was very little of this variety, Lakhapur, available at the Farm for **rab**-making, but the **rab** it yielded was, to say the least, in no way inferior to that of S. 48 in respect of richness and strength of crystals. Further trials were put off till the next season in order to form a definite opinion as to which of the two varieties was superior in respect of the yield and the quality of the white sugar. As far as the natural colour of **gur** or **rab** is concerned, S. 48 was found far superior to the other.

Exhaustive trials in the manufacture of white sugar could not be made with the **rab** of Co 214, as he greater part of the crop had to be utilised for the determination of the outturn of **gur** per acre, and

only a limited quantity of this cane could be used for preparing **rab.** The figures of white sugar obtained are noted in the annexed table.

Date of machining the **rab.**	Date on which the **rab** was boiled.	Field No.	Variety of cane.	Quantity of **rab** machined.	Quantity of undried sugar obtained	Quantity of dried sugar	Percentage of undried sugar to machined **rab.**	Percentage of dried sugar to machined **rab.**
				lb. oz.	lb. oz.	lb. oz.		
6.3.25	1 pot boiled on 14.12.24	15	Co.214	28–4	11–13	11–8	84.41	40.78
31.3.25	1 pot boiled on 10.1.25	12	Do	23–8	10–10	10–5	45.10	43.82
	Total			51–12	22–7	21–13	43.36	42.10

The results were not conclusive for, as already explained, small charges in the centrifugal lost too much during the washing, as compared with the larger normal ones.

Rab made from a ratoon crop of Co 214 which however had the disadvantage of receiving only two waterings during the hot weather gave the following result on being machined :—

Date of machining the **rab.**	Date on which the **rab** was boiled.	Field No.	Variety of cane.	Quantity of **rab** machined.	Quantity of undried sugar obtained	Quantity of dried sugar	Percentage of undried sugar to machined **rab.**	Percentage of dried sugar to machined **rab.**
				lb. oz.	lb. oz.	lb. oz.		
24.3.25	2 pots boiled on 7.3.25	18	Co 214 (ratoon)	90–8	36–8	35–9	40.33	39.22

The **rab** from a ratoon crop of S. 48 which also had only two waterings in the hot weather yielded only 39.46 per cent of first sugar. The comparatively low outturns may be attributed to poor growth.

Co 221 gave a very high yield of superior **gur** per acre but the crop suffered from fungus disease later in the season. Experiments in making **rab** suitable for the centrifugal were therefore unsuccessful and had to be postponed to the next season.

Yuba (S. 39 of Shahjahanpur) while good enough for **gur** making did not give a high yield of white sugar because of the weakness of its **rab** crystals and of the sticky nature of its molasses, for which reason copious washings were necessary before the desirable degree of whiteness was attained, in other words, undue losses in washing were unavoidable. The following figures were obtained in the course of trials but the resulting product was only a pale sugar :—

Date of machining the **rab.**	Date on which the **rab** was boiled.	Field No.	Variety of cane.	Quantity of **rab** machined.	Quantity of undried sugar obtained	Quantity of dried sugar	Percentage of undried sugar to machined **rab.**	Percentage of dried sugar to machined **rab.**
				lb. oz.	lb. oz.	lb. oz.		
30.3.25	4 pots boiled on 31.1.25	Riazul Asmar	Yuba.	155–8	70–6	68–0	45.20	43.72

The yields obtained from the imported varieties described should now be compared with those of Indian indigenous varieties (**Nasik Khadia and Dhaul**) grown side by side at the Farms of Bhopal

The following are the results of machining samples of the **rab** of the two last named varieties :—

Date of machining the **rab.**	Date on which the **rab** was boiled.	Field No.	Variety of cane.	Quantity of **rab** machined.	Quantity of undried sugar obtained	Quantity of moist dried sugar	Percentage of undried sugar to machined **rab.**	Percentage of dried sugar to machined **rab.**
				lb. oz.	lb. oz.	lb. oz.		
15.3.25	1 tinful boiled on 4.3.25 (not limed)	$\frac{9}{2}$	**Nasik Khadia.**	56–6	18–12	18–4	33.26	32.37
15.3.25	1 tinful boiled on 5.3.25 (partially limed)	Do	Do	64–12	24–13	24–6	38.30	37.52
24.3.25	3 tinfuls boiled on 5.3.25 (partially limed)	Do	Do	133–0	50–0	48–4	37.59	36.27
30.3.25	1 tin boiled on 10.3.25 (limed)	Do	**Dhaul**	49–12	19–4	18–13	38.69	37.78

The difference in the outturn of white sugar from **rab** made with limed and unlimed juice should be marked.

A boiling of the juice of mixed canes grown on the farms, of all types including indigenous varieties and ratoon crops, gave a yield of 39.54 per cent of dried sugar on the **rab** when it was machined.

The above observations, based as they are on actual facts and figures, led to the following conclusions :—

(1) That an average outturn of over 46 per cent of perfectly white sugar might be obtained in actual practice at that stage from the **rab** of selected canes such as S. 48 and P. O. J. 33 provided that the system of boiling was employed as elaborated in Bhopal, with a view to minimising the charring of the **rab** and accelerating the evaporation of moisture from the boiling liquor. The **rab** must also be treated in the centrifugal with judicious washing of the crystals. If the manufacture of the white sugar was to be the chief consideration, undoubtedly the **rab** of S. 48 and P. O. J.33 should be given preference over any other canes grown until then in Bhopal.

(2) That it was probable that the **rab** prepared from Co 214 and Co 221 might yield as well as S. 48 or nearly so, if the cultivation was carried out on improved lines and the crop was harvested before it was over-ripe, provided, of course, that Co 221 did not prove again to be liable to fungus disease in the Malwa climate.

(3) That Yuba (S. 39 of Shahjahanpur) was the poorest of the imported canes for the manufacture of **rab** and white sugar, as the **rab** besides being poor, deteriorated on storage.

(4) That the indigenous thin canes grown in Malwa were all inferior to the imported and seedling canes, so far as the yield of of white sugar was concerned.

(5) That in spite of their general inferiority the indigenous canes **Ledu, Bhelsai, Dhaul** and **Nasik Khadia** yielded about 40 per cent of white sugar from the **rab** when the latter had been prepared under the improved method of boiling. Even this yield was quite appreciably higher than the average obtained in the United Provinces with the better varieties of local thin canes ordinarily employed there for sugar manufacture.

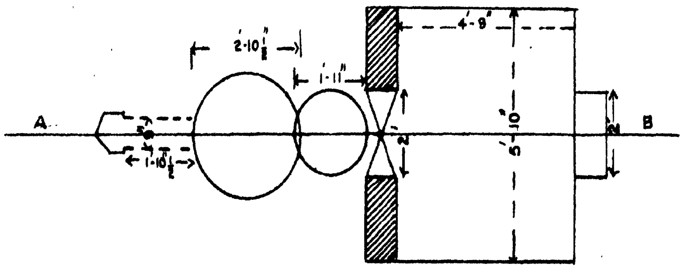
2. Second Sugar. The following observations are made in accordance with the experience gained during this season :—

The molasses separated from the **rab** by means of the centrifugal and collected in kerosene tins at the foot of the machine should be treated **without delay** for the manufacture of either second **gur** or second **rab** for both of which purposes it had been

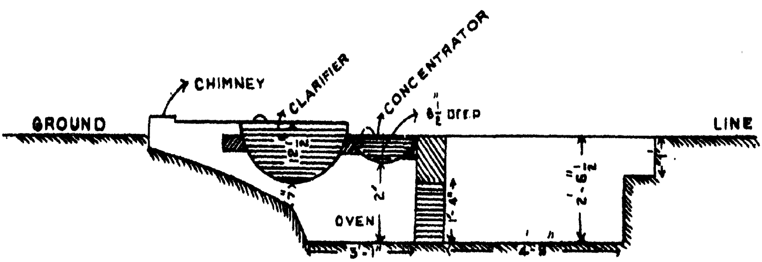
ILLUSTRATION NO. VI

PANS AND FURNACE FOR BOILING GUR OR MOLASSES INTO RAB

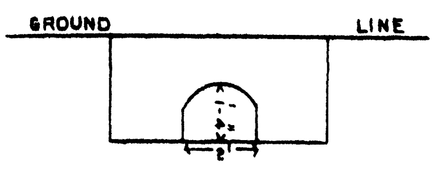
PLAN



SECTION ON A. B.



FRONT ELEVATION



found by repeated trials to be suitable, if carefully boiled. There was enough sucrose, specially, in the case of S. 48 and P.O.J. 33, to enable the resulting **gur** to solidify on the **chak** or the **rab** to crystallise in the pots. The crystallisation took place better in pots rather larger and having a wider mouth than those used ordinarily for potting the first **rab.** In the earlier stages of the sugar-boiling season, when the cane was not fully ripe, it might be found desirable to add a certain proportion of clarified whole juice to each charge of molasses in the concentrating pan of the boiling plant in order to ensure proper solidification of the **gur** or crystallisation of the **rab.**

Experience would suggest the proper quantity of liquor to be added under these circumstances. If juice was not available, **rab** crystals or rich **gur** might be added instead, but as the season advanced no such additions were required. In order to recover the available sugar completely, broken pieces of the pots were washed with clean water, and then boiled in a pan until all the sugar absorbed by the pots had been dissolved out. This sugar solution was strained through a thin cloth and then poured into the molasses while it was boiling. The operation of boiling was carried on in a system of two iron pans specially suitable for the process placed on a furnace of special construction as illustrated opposite this page (Illustration No. VI).

When the proper consistency had been attained, the boiling mass was transferred to the **chak** in the case of **gur** and to the receptacles for airing it in case of the **rab.** Afterwards the **rab** was potted. If the colour of the boiled molasses when attaining the consistency of **gur** was not sufficiently light, a few drams of carbonate of soda or finely sifted **reh** (crude natural sodium carbonate) sprinkled and stirred into the material lying on the **chak,** while it was still hot, brought about a remarkable change for the better in the colour of the resulting **gur.** There was of course a perceptible evolution of the carbonic acid gas due to the partial neutralisation of acids present which was no doubt responsible for the improved colour. It was found not advisable to give this treatment when the molasses were boiled into **rab** for making second sugar.

The boiling of molasses should never be entrusted to laymen or even professional **rab**-boilers not specially trained in the boiling of molasses. In Rohelkhand there is a class of professional men who chiefly work in this particular branch of the native sugar industry and are experts. There, it is customary to convert into **rab** all exudations from the **khanchi** which is a mass of sucrose covered by the **sewar** layer. An inferior sugar can be extracted from it with the help of the **sewar.** Sometimes the exudation is converted

into **gur**. The **shira** or molasses obtained by the separation of the **potli** (brown crystals) in woollen bags cannot be converted into **gur** or **rab** because of excessive fermentation and inversion of the sugars due to exposure as a consequence of the slow elimination of the molasses and the long time for which it has to remain in the molasses reservoir. This grade of molasses being unfit for sugar production has to be sold of necessity either to the Indian tobacconist or the distiller who practically dictates his own terms and purchases it at a much lower price than the molasses ought to be worth for sugar-making. It is here that the use of the centrifugal is specially advantageous to the manufacturer in-as-much-as it enables him to separate the molasses quickly and to immediately re-boil it into either a readily saleable form of **gur** or into **rab** capable of yielding a marketable sugar though, it may be, slightly yellow or pale in colour. With more experience of making sugar with the centrifugal, the machine seemed likely to prove itself indispensable and worthy of universal adoption by the trade. Success in the manipulation of the molasses for the production either of **gur** or of crystalline sugar depended entirely on the workman who should be chosen from among a special class experienced in handling molasses as in Rohelkhand. It was also necessary to boil the molasses fresh in moderate quantities at a time, and with all possible speed. Each charge in the **parchha** (concentrator) should not exceed two tinfuls (about 100 pounds). If heavier charges were employed more time and slower boiling would be the result, favouring inversion of the sucrose and the resulting **gur** or **rab**, as the case may be, would materially suffer in quality; probably the **gur** would not solidify and the **rab** would develop only poor crystals likely to escape through the mesh of the centrifugal. There was little doubt that where failure in the production of **gur** or crystalline sugar from molasses had taken place under open pan boiling, it had been due more to the want of skill on the part of the boiler than to the low sucrose content or to any other cause. The expert boiler of Rohelkhand had proved capable under proper guidance of meeting every contingency likely to arise.

If all proper care had been taken in the boiling process, the **gur** would neither be soft in texture, nor unsightly in colour, nor unpalatable to the taste. Indeed the taste of the second **gur** was pronounced by the connoisseurs of Bhopal to be very agreeable. In Bhopal it easily commanded a price of 4 local seers (9.89 lbs) to the rupee while the first **gur** produced at the factory was selling at 3 to 3¼ local seers to the rupee.

The yield of **gur** from molasses was about 80 per cent, or a little more, of the weight boiled, while the weight of **rab** obtained from the molasses had by repeated determinations been found to be on the average 82.5 per cent of the molasses boiled.

The second **rab** when machined had, according to the sucrose content of the molasses boiled, yielded from 37 to 40 per cent of its weight as a pale sugar. Usually the molasses of S. 48 and P. O. J. 33 yielded a distinctly higher percentage of this second sugar than the molasses from other canes, those from the indigenous thin varieties being very poor. The second sugar was however highly agreeable to the Indian taste and would sell readily in the market at Rs. 14/- to Rs. 15/- per local maund (98.7 lbs.)

No attempt was made to extract a third sugar from the molasses and distillation of alcohol was forbidden by the State, but fortunately there was ample demand for the final molasses by the tobacconists within the territory. Even with S. 48 and P. O. J. 33 there was little hope of a third sugar being extracted profitably.

3. Total (average) recovery of first and second sugars.

With the foregoing data the average total recovery of both forms of sugar was calculated as follows, assuming that a small factory for the production of white centrifugal sugar was worked at a sugar plantation in which S. 48 and P.O. J. 33 were the predominent varieties under cultivation :—

100 parts of cane yielded 67.0 parts of juice	(a very fair average if the three-roller Chattanooga and the three-roller "Hathi" mill of Messrs. Burn & Co. of Calcutta were used with bullock power for crushing the cane.
67 parts of juice yielded 14.07 parts of **rab.**	Equivalent to 21 per cent yield (this was a fair average for the two canes mentioned, with the improved system of boiling).
14.07 parts of **rab** yielded 6.55 parts of	white first sugar equivalent to 46.6 per cent yield.
and 7.52 „	first molasses.
7.52 „ „ molasses yielded 6.20 „	second **rab** if re-boiled fresh.
6.20 „ „ second **rab** yielded 2.41 „	second sugar (of polarisation value 88.7 after storage of three or four weeks, equivalent to 39 p.c. yield.)
and 3.79 „	of second molasses.

The net figures of recovery from the **rab** therefore were :—

rab	14.07	First sugar	6.55
		Second sugar	2.41
		Total sugar	8.96
		Second molasses	3.79
		Loss of weight .. .. .. (water evaporated)	1.32
rab	14.07		14.07

It thus became clear that at least with S. 48 and similar rich canes very nearly 9 per cent of marketable sugar was actually extracted from the cane under the processes developed at Bhopal as compared with 4 per cent found by the Indian Sugar Committee (vide page 268 para 279 of their Report) to be recoverable by the Rohelkhand manufacturer under the old **khanchi** system, or with 5.6 per cent recovered by Mr. Hulme using his open-pan system at Nawabganj (Rohelkhand) or with the 9.5 per cent which the Committee considered possible in a thoroughly efficient factory. The author did not pretend to possess any practical experience of modern sugar factories, but by earnest endeavours to improve the indigenous industry he had been able to obtain the above results using simple methods easily capable of adoption by any average Indian manufacturer, who could afford to purchase a centrifugal machine. With further investigations and research there seemed to be no reason why the yields obtained in the field and at the factory should not improve further, both in quality and quantity. In 1911, at Ooragahalli in Mysore, experiments were also made for extracting white sugar by means of a centrifugal following an open-pan system of boiling the **rab,** with the result that 21.23 per cent of **rab** was obtained from the juice and only 41.5 per cent of white sugar (9.0 per cent on the juice) from the **rab.** At Bhopal the total recovery of sugar was 13.37 per cent of the juice (8.96 of sugar having been recovered from 67 of juice).

B. Second Research Season (1925–26).

During this season the canes of the superior varieties were available in large quantities to experiment with, though their quality was unfortunately inferior compared to the previous season as an inevitable result of extraordinarily early cessation of the monsoon rains in the latter part of August 1925, which more or less stunted the growth of crops and hampered normal development of sucrose in the juice. However in spite of the initial disadvantages caused by these adverse circumstances the results in every branch of work were more satisfactory than before as will be seen presently.

The new boiling-plant consisting of 5 pans which had not yet passed its experimental stages, was, after several modifications in the size of the different pans and their patient trials on differently shaped ovens to secure the maximum rapidity of boiling and richness of the **rab,** was perfected, the dimensions of the vessels and the various heating chambers being finally standardised. A detailed description of the new system of the pans and of the furnace construction will be found in chapter XI.

At the commencement of the season Messrs Thomas Broadbent and Sons, to whom the recent mechanical requirements of sound sugar curing suggested by the improved forms of the massecuite to be treated now in the centrifugal had been explained by correspondence, furnished a new 18″ diameter self-balancing hand centrifugal of suspended (Weston) Type 16 capable of running at a speed of 1800 revolutions per minute without extra strain on the labourers and lined with fine copper cloth protected outwards by a coarse but strong copper mesh. This proved a highly efficient machine so far as perfection in quick separation of molasses from the **rab** was concerned, the fineness of the copper lining preventing all undue escape of sugar crystals from the cage, and the high speed, uniformly maintained by ordinary hand labour, brought about a rapid and continuous elimination of the molasses. The holes in the steel drum having been made closer, the action of the air in driving out the moisture was more efficient as a result of less resistance. In consequence of these improvements in the machine, the yield of first sugar from the **rab** was very distinctly higher than in the previous season, while that of the second sugar from the first molasses, remained about the same as before, this second sugar being white instead of pale or yellow. The ultimate gain is thus obvious. The recent improvements in the machine have been embodied by the makers in their type 16 which seems now to have a good future for it in India. It was by this machine that as much as 58 per cent of sun-dried sugar was obtained from the best **rab** produced with rich canes in Bhopal. It has been described and illustrated in chapter XIV.

Persistent and prolonged efforts were made again to introduce liming in the open-pan system with and without the mucilaginous defecants, the lime being put in before and after these were used, but although it improved crystallisation slightly in the earlier stages of the season when the cane was unripe, the colour of the resulting sugar when cured was not altogether satisfactory. The conclusion that lime should be used only sparingly in the shape of saturated limewater and not until after the defecation, was confirmed.

It was found that **sajji** water already in use in the boiling industry could with advantage be employed in greater quantities as it helped to increase the crop of crystals in the **rab** and to lessen

viscosity. Though the colour of the **rab** was then darkened, that of the crystals remained unaffected.

The use of sodium hydrosulphite confined in the preceding year to the clarifying stage of the juice was successfully introduced in the curing of the **rab.** It was established by careful observations that the mixing of a weak solution of the chemical with the **rab,** enough to change the colour of the mass into an orange yellow before the latter was put into the centrifugal machine, counteracted the viscosity, brightened the first sugar and improved the colour of the first molasses, which after this treatment yielded whiter second sugar than before. This agent has thus proved as much a necessity for bleaching the liquor in the boiling pan as for improving the quality of sugar in course of purging the **rab,** though it should be employed with sufficient care in small quantities, any excess being liable to impart a pale tinge to the resulting first sugar.

An area of 0.09 acres of an average crop of S. 48 harvested when ripe yielded 3804 lbs. of cane after removal of top sets required for planting, the tops weighing 776 lbs. The former quantity when crushed by 3-roller iron mills worked by bullock power, yielded 2651 lbs. of juice (69.68 p.c. of the weight of cane) which on boiling gave 536 lbs. of **rab** (20.25p.c of the weight of juice). According to these data the yield of **rab** per acre from the crushed cane calculated to 72.5 standard maunds.

If the top sets had been crushed for boiling **rab** instead of being used for propagation, it is calculated that a further yield of **rab** estimated at 12.5 maunds per acre was possible. The yield from the whole cane may thus be taken to amount to 72.5 plus 12.5 equal to 85 maunds of **rab** which is at least double of the yield obtained from indigenous canes grown under high cultivation in Bhopal.

This **rab** when treated in the belt-driven hand power Weston centrifugal (Broadbent's type 16), yielded 51.5 p.c. of its weight of white first sugar of superior white colour (as it came out of the centrifugal and before it was dried in the sun) leaving 49.5 p.c. of first molasses. The latter when reboiled and thoroughly clarified gave 78 to 80 p.c. of its weight as second **rab.** The latter when passed through the centrifugal on complete crystallisation of the cane sugar, having been treated with sodium hydrosulphite, yielded 37.2 p.c. of its weight of fairly white sugar ,as taken out

of the machine. As a result of these experiments the following figures were arrived at :—

100 cane = 70 juice (assumed) (actually 69.68 was extracted but some of the mills used were inferior).
= 14.17 of first **rab.**
= 7.30 of first sugar (undried) and 6.87 of first molasses.

6.87 of first molasses gave 5.36 of second **rab** on re-boiling; 5.36 of second **rab** yielded 1.99 of white second sugar as discharged from the centrifugal (37.2 per cent) plus 3.37 of second molasses.

Thus 100 cane = 14.17 first rab.
= 7.3 (first white sugar)
plus 1.99 2nd white sugar
Total 9.29 undried as discharged from the machine).

Deduct loss of moisture in drying the two sugars. } .23 (2½ p.c. of the weight of the undried sugar).*

9.06 (net recovery of marketable sugar per 100 of S. 48 cane.)

The 1st **rab** 14.17 may be accounted for as follows :—

Net recovery of marketable sugars	9.06
Second molasses	3.37
Loss of moisture in drying the sugars.. ..	0.23
Loss of moisture in boiling the 1st molasses into 2nd **rab**	1.51
	14.17

An experiment on similar lines was carried out with another rich cane P.O.J. 33 (Lakhapur) which gave 75 p.c. of its weight of juice when crushed with 3-roller bullock power mills. In this case the yield of white first sugar amounted to 7.9 per cent and of white second sugar to 2.3 per cent on the cane, the total recovery of both sugars on 100 of cane being 10.20. This result was so extraordinary that it has considerably surprised the author and

* This is an assumed figure based on several experiments made during the Season 1925-26 to determine loss of weight in drying the sugar in the sun. Indian **khand** usually absorbs moisture from the air and it is therefore very difficult to determine the loss by evaporation with strict accuracy.

but for the fact that it had been carried out with all due care he would not have mentioned it at this stage in the book. Apparently the high extraction of the juice and its richness account for the high yield of total sugar in this case. Experiments with this variety should, it was decided, be carried out in the seasons to come.

A number of tables are subjoined to show the yield of white 1st sugar from first **rab,** prepared during the season 1925-26, under the improved method of boiling from some of the richer canes grown at the Bhopal Farms. From these statements it will be seen how the yield varied from field to field according to the varieties of the cane, the stage of growth, the richness or purity of the juice and the time allowed to the **rab** for crystallisation of the cane-sugar.

Statement no. I. showing the yield of white 1st. centrifugal sugar (khand) from the 1st rab of cane variety S.48. (Season, 1925-26.)

Date of machining the **rab**	Date on which the **rab** was boiled	Variety of cane	Field No	Quantity of **rab** machined	Quantity of undried sugar obtained	Percentage of undried sugar to machined **rab**	Percentage of dried sugar to machined **rab**
				lbs. oz.	lbs. oz.		
4.1.26	26.12.25	S.48	20	106-4	56-11	50.35	
5.1.26	29.12.25	,,	,,	157-4	76-1	48.37	
6.1.26	1. 1.26	,,	,,	179-12	87-9	48.71	
6.1.26	1. 1.26	,,	,,	90-0	43-3	47.98	
25.2.26	10. 2.26	,,	,,	145-0	80-2	55.26	
16.3.26	10. 2.26	,,	,,	43-12	26-10	60-85	
				722-0	370-4	51.28	50.27
24.2.26	16. 2.26	,,	12	114-0	57-10	50.54	
16.3.26	26. 2.26	,,	,,	135-14	64-3	47.24	
21.4.26	7. 2.26	,,	,,	32-0	17-0	53.12	
				281-14	138-13	49.24	48.01
22.4.26	13. 2.26	,,	6/1	300-12	162-4	54.7	53.34
25.2.26	14. 2.26	,,	7	91-10	43-14	47-88	46.69
Grand total of all the fields. ..				1396-4	715-3	51.23	49.65

Statement No. 2 showing the yield of white 1st centrifugal sugar (khand) from the 1st rab of cane variety P. O. J. 33 (Lakhapur) made during the season 1925-26.

Date of Machining the **rab**	Date on which the **rab** was boiled	Variety of cane	Field No.	Quantity of **rab** machined	Quantity of undried sugar obtained	Percentage of undried sugar to **rab** machined	Percentage of dried sugar to machined **rab**
				lb. oz.	lb. oz.		
12-1-26	7-1-26	P.O.J.33	12	93-8	44-5	47·39	
16-1-26	7-1-26	,,	,,	66-0	32-14	49·81	
24-1-26	9-1-26	,,	,,	232-0	120-0	51.72	
24-2-26	10-2-26	,,	,,	100-0	55-4	55·25	
10-3-26	26-2-26	,,	,,	108-6	54-2	49·94	
16-3-26	26-2-26	,,	,,	214-12	108-6	50.46	
		Total	..	814-10	414-15	50.94	49.67

Statement No. III showing the yield of white 1st centrifugal sugar (**khand**) from the first **rab** made with cane varieties Co 221 and Co 214.

Date of machining the **rab**	Date of boiling the **rab**	Variety of cane	Field No.	Quantity of **rab** machined	Quantity of undried sugar obtained	Percentage of undried sugar to **rab** machined	Percentage of dried sugar to machined **rab**
				lbs. oz.	lbs. oz.		
24-2-26	11-2-26	Co 221	25	34-8	16-10	48.17	
12-3-26	18-2-26	,,	,,	74-0	35-4	47·63	
11-3-26	7-1-26	,,	,,	128-0	59-0	46.09	
17-3-26	18-2-26	,,	,,	128-8	63-4	49.22	
17-3-26	18-2-26	,,	,,	239-8	114-10	47.86	
22-4-26	11-2-26	,,	,,	110-0	52-0	47.27	
		Total	..	714-8	340-12	47.69	46.5
2-2-26	23-1-26	Co 214	12-22	108-8	44-6	40.98	
2-2-26	23-1-26	,,	,,	33-0	14-3	42.99	
		Total	..	141-8	58-9	41.43	40.40

Referring to statement No. I, the reader will see that the average yield of sun-dried first sugar in the case of S. 48 was 49.9 p.c. of the weight of **rab** machined and varied up to 60.85 p.c. when fresh from the centrifugal or 59.64 p.c. when dried in the sun. Some of the figures in the statement which show lower percentages of the yield resulted invariably as a consequence of machining **rab** specimens of damaged, poor, unripe or over-ripe canes or of imperfectly clarified juice, not boiled with the maximum rapidity possible, or over-washing of the crystals by zealous but inexperienced centrifugers. The best period for harvesting this variety (S.48) in the Bhopal climate seemed to lie between the first week of January and the middle of February after which the crop lost in richness of the juice and went on deteriorating.

With reference to statement No. II, it should be observed that P. O. J. 33 is a much thicker cane than S. 48. The juice of this variety, when clarified is of a somewhat dark colour, yielding generally a dark-coloured **gur** very rich in crystals, and the **rab** obtained from it is also dark, unless the juice has after clarification been bleached by a liberal use of the sodium hydrosulphite. It is not as good for making **gur** as for preparing **rab** in which the crystals of sugar remain unaffected by the dark colour of the juice. During the season 1925-26 the yield of white first sugar from the **rab** of this variety averaged 48.85 p.c. of the weight of **rab** and went upto 55.25 p.c. of undried or 53.85 of sun-dried sugar, the higher percentages of yield shown in the statement having been obtained from specimens of **rab** in the preparation of which **sajji** had been used more freely than is customary for clarification. It should be remembered that the largest percentage of total sugar (10.20 on 100 of cane) was in the Bhopal experiments obtained so far only from this variety but it had yet to be seen whether S. 48 would not give a similar or a higher yield when the juice of that cane received the same treatment with **sajji** water.

A glance at statement No. III will show that Co 221 and Co 214 were both inferior to S. 48 and P. O. J. 33 with regard to the yield of white sugar, although in the experiments in the manufacture of **gur** they had proved good yielders, the colour and quality of their **gur** being highly satisfactory.

Of the indigenous varieties only the **rab** of **Munhtora,** when prepared under the improved system yielded up to 45% of white first sugar. Other varieties **Nasik Khadia, Dhaul, Bhelsai, Ledu, Kansia, Mandkia** and even Yuba (S. 39) were discarded as unsuitable for production of white sugar. Ratoon crops of these varieties too failed to give good results, the **rab** being found capable of giving only 40% of first sugar or less and in some cases pale.

Rab made from S. 48 grown dry yielded a maximum of 49.81 and a minimum of 45.23 per cent of white sugar.

Much was expected from 247. B but the **rab** from this variety grown under intensive cultivation gave only 44.29 of undried or 43.19 of sun-dried white sugar. Further trials were considered necessary to determine the sugar-yielding merits of this highly spoken of variety.

The following table gives the results of experiments in making second sugars from the 1st molasses of the **rab** of the three main varieties of cane grown for the production of white sugar :—

Date of boiling the 1st molasses	Date of machining the second **rab.**	Variety of irrigated cane.	Field No.	Quantity of second **rab** machined.	Quantity of sugar obtained	Percentage of undried 2nd sugar to 2nd **rab** machined	Percentage of dried second sugar to 2nd **rab** machined	Colour of 2nd sugar obtained
				lb. oz.	lb. oz.			
23-2-26	18-3-26	S.48	6	77-4	25-14	33.49	..	Fairly white.
24-2-26	18-3-26	„	12	46-12	16-14	36.09	..	„
			Total ..	124-0	42-12	34.47	33.61	„
24-2-26	18-3-26	P.O.J. 33	12	44-10	18-8	41.45	..	„
11-3-26	20-4-26	„	8	18-0	7-8	41.66	..	„
			Total ..	62-10	26-0	41.53	40.5	„
17-3-26	17-4-26	Co 221	25	63-12	20-2	31.5	..	„
17-3-26	18-4-26	„	„	100-14	30-15	30.66	..	„
			Total ..	164-10	51-1	31.02	30.25	„

An examination of the above figures will show that P. O. J. 33 gave the highest yield of the second sugar, S. 48 stood next and Co 221 came third. Thus from every consideration chemical, agricultural and commercial P. O. J. 33 and S. 48 were until this season, found to be the two best varieties suited to Bhopal conditions. A large number of varieties of famous exotic and Coimbatore seedling canes were brought under experimental cultivation at the Bhopal Farms during the season, and it seems probable that among them varieties equally good or even better might be found. The most promising of these were Manjav, White Transparent, 208 B, D.109, Patta Patti, Co 210, Co 205, Co 213 and Co 281.

It was determined that, speaking generally, all thick canes required more watering than the thin and medium varieties and more manure. All white canes were more suitable for production of superior **gur** than the red ones, but being generally soft were more liable to the attacks of the great enemy pest **Chilo Simplex,** especially if planted late in the season. These should therefore be planted early and as near the irrigation well as possible.

Red canes required less waterings, resisted drought and heat much better, specially the Co 213. They were less liable to attacks of the Chilo, and if attacked, a very large number of new shoots sprang up and the plants recovered their vigour admirably during the rains. They are generally high yielders of **gur** as well as of white sugar, and are decidedly more valuable both from the grower's and the manufacturer's point of view for Malwa soil and climate. Most of them flower in years of good normal rainfall though the seed formed does not mature.

Influence of the consistency of the rab on the yield of white first sugar.

In the chapter on boiling **rab,** reference has been made to the various consistencies of **rab** which go by certain trade names well understood by the boilers and manufacturers.

The consistency of **rab** has a very important bearing on the yield of sugar in the centrifugal and it will be interesting and advantageous to the business man to know how the yield varies with the consistency and what should be regarded as the economic value of the **rab** of the various degrees of thickness for purposes of sugar production. The following table gives figures representing the merits of the main consistencies known to the trade. Cane S.48 from the same field was crushed on the same day

for each experiment, the same mills being employed and the same method of boiling used in each case.

Date of crushing the cane and boiling the juice	Weight of cane crushed	Weight of juice obtained	Percentage of juice to cane	Weight of **rab** obtained	Percentage of **rab** to juice	Consistency
1	2	3	4	5	6	7
25th Jan.	lb. oz.	lb. oz.		lb. oz.		
1926.	700–0	480–0	68.57	101–8	21.14	**Mohrjam**
,,	700–0	480–0	68.57	102–0	21.25	**Jaukhasi**
,,	700–0	480–0	68.57	103–0	21.45	**Mota Dora**
,,	700–0	480–0	68.57	103–8	21.62	**Sharbati**

Date of machining the **rab**	Weight of **rab** machined	Weight of 1st sugar obtained	Percentage of first sugar in **rab**	Percentage of 1st sugar in juice	Percentage of sugar in cane
8	9	10	11	12	13
3rd. Feb.	lb. oz.	lb. oz.			
1926.	101–8	50–8	49.75	10.52	7.21
,,	102–0	49–15	48.95	10.40	7.13
,,	103–0	44–2	42.83	9.19	6.30
,,	103–8	39–15	38.58	8.31	5.70

It was clear from the above statement that the two consistencies **Mohrjam** and **Jaukhasi** were the most profitable from the manufacturer's stand point. Instead of leaving the management of the boiling shed almost entirely to the boiler or the low

paid **Darogha** of the **bel,** the manufacturer would be well advised to supervise the boiling himself and insist on attaining the proper consistency. There is no doubt that when **rab** of the **Mota Dora** or the **Sharbati** class is machined, the crystals obtained are larger and more brilliant, but the quality of the sugar obtained from the first two consistencies from the machine is so superior, and the quantity of the yield so much higher, that it is not worth while sacrificing a high percentage of first sugar merely for the sake of getting slightly larger and more shining crystals by boiling **rab** of thinner consistencies. Such crystals, it should be observed, fetch no higher price in the Swadeshi market.

There is no doubt however, that the 1st molasses yielded by the thinner massecuites is comparatively rich in sucrose and that fact accounts for a higher yield of second sugar from such molasses. The quality however of the second sugar is naturally inferior and the policy of the manufacturer should therefore be to extract as high a percentage of white first sugar as possible, rather than a low yield of white 1st sugar and a comparatively high yield of inferior second sugar. This object can easily be secured if the boiling of the first **rab** is controlled as indicated above.

Another experiment in this direction carried with P.O.J. 33 variety grown in a field having poor soil may be cited here. **Rab** was boiled to two consistencies **Mohrjam** and **Mota Dora** under similar conditions: the former yielded in the centrifugal 47.87% of white first sugar on the **rab** and the latter only 43.75%. The molasses was not boiled for second sugar.

C. THIRD RESEARCH SEASON (1926—27.)

The seasonal conditions during the year were particularly unfavourable to the growth of **kharif** (rain) crops in general and the sugarcane in particular.

The cane crops had a good start, but the heat during the summer was excessive, the temperature in the shade being at times as high as 110°F & over. The monsoon rain held off till the end of June and winds nearly as hot as those characterising the hot weather of the Gangetic plain in Upper India prevailed throughout the month;

with the result that the unirrigated cane crops were practically destroyed while the wells on which the irrigated areas depended failed to cope with the daily demand for water requisite for the healthy progress of the young plants. The notorious enemy, **Chilo Simplex** played havoc in several fields, specially those planted during the later stages of the season. In fields which received only a mild attack of the pest almost every next plant had some of its leaves dried up, so that the crops presented a variegated appearance. The first monsoon shower was received on the 1st of July, and the crops recovered admirably in the course of the month, but unfortunately the falls during August and September were far in excess of the requirements, the total during the 3 months amounting to 46.05 inches which is about 28 p.c. above the normal. Water stagnated badly in fields and the choice had to lie between allowing the crops to suffer from the injurious effects of undue accumulation in the fields, and draining it off as frequently as was found necessary. The latter course involved the inevitable loss of valuable manurial matter, but being the lesser evil was chosen for adoption. In all fields liable to stagnation, the growth was consequently stunted, while on high lands it was so luxuriant as to cause "lodging" of canes and the consequent abnormal development in them of uncrystallisable sugar at the expense of the sucrose. The plastic nature of the black soil rendered it impossible to earth up the plants and with much difficulty they were raised and tied up to bamboo posts sunk into the ground.

The rains ceased early in October, but unlike normal years no showers were received in the winter rendering artificial irrigation necessary during the crushing season. Not long after the milling operations were started, there was frost on two occasions which damaged the ripening crops in general quite appreciably. Whether as a result of excessive rains, or of other circumstances, two of the thick varieties, the Local Paunda and the **Lakhapur** (P.O.J. 33) were attacked by red rot (the latter for the first time in Bhopal).

From the experimental point of view however, the peculiarly bad weather conditions which prevailed during the year cannot be regarded as altogether deplorable, in-as-much-as they furnished the author with opportunities of testing the merits of his processes during a particularly adverse season, and of satisfying himself that

even in an unfavourable year the new methods of preparing the massecuite and producing white sugar from it gave sufficiently pleasing results.

The main improvement in the boiling plant was the addition of an extra pan (Hauz I) to the set and it is this improved set that has been described in chapter XI of this book. This modification has raised the boiling capacity of the plant from 75 standard maunds of juice boiled before with 5 pans, to over 90 maunds dealt with now in a working day. Corresponding modification was effected in the furnace.

As a much larger area for conducting experiments in the production of white sugar from different varieties of cane, at different stages of the seasons, was available than in the previous season, opportunity was taken of carrying them out again and again from the canes of the same fields and comparing the results which varied with the varying degrees of ripeness of the crop. The opportunity of making comparative determinations of the yield of white sugar (1st and 2nd) and of molasses from different varieties grown under different conditions in different fields was also availed of. Special attention was paid to proper utilisation of the 1st molasses for extraction of the 2nd (white or slightly "off" colour) sugar, which forms one of the main features of profitable sugar-making under the new method, and to the determination of the yield of the same from different varieties. If, as in the old **khanchi** system, the second sugar is not extracted, a distinctly smaller monetary return will be obtained. The second molasses resulting from the production of second sugar commands the same market value as the first molasses of the old system, if not higher, as the tobacconist who is the chief consumer readily appreciates the bright orange colour, the density and the more agreeable flavour of the second molasses obtained in the new system.

In each experiment a weighed quantity of stripped canes was taken after removing the tops for seed purposes. This was crushed with efficient bullock power mills, the juice being weighed and boiled, and the massecuite potted in kerosene tins or galvanised iron tanks and given sufficient period of storage to crystallise. It was then cured in the centrifugal to obtain first white sugar, the weight of the product being carefully recorded. The first molasses was boiled while fresh, potted similarly and stored in tins until the crystallisation was complete and the weight of the material determined. The second massecuite was then machined to extract the second sugar the weight of which was noted, the quantity of second molasses being calculated by difference. The results of these carefully conducted trials are tabulated in the following statement:—

Statements showing results of experiments in manufacture of white sugar direct from cane at the Sugar Research Station, Nuzhat Afza Bhopal, Season, (1926-27.)

Name of cane variety.	Farm and field no. in which the crop was grown.	Whether plant crop or Ratoon crop.	Date of boiling the juice.	Percentage of sucrose.		Weight of cane crushed.	Weight of juice obtained.
				in juice	in cane		
1	2	3	4	5	6	7	8
						Plant	**or First.**
S. 48	Nuzhat Afza 31	Plant	9-1-27	16.84	12.82	460 lbs	292 lbs
,,	,, ,,	,,	16-1-27	19.49	16.01	1452 ,,	993 ,,
,,	,, 26	,,	13-2-27	19.72	15.41	1820 ,,	1175 ,,
,,	,, 23	,,	4-3-27	19.88	15.99	1000 ,,	658 ,,
Manjav	,, 23	,,	31-12-26	18.23	14.12	1551 ,,	942 ,,
,,	,, ,,	,,	17-1-27	15.43	13.96	520 ,,	358 ,,
,,	,, 15	,,	9-1-27	16.06	13.96	692 ,,	466 ,,
,,	,, ,,	,,	21-2-27	18.88	15.43	1918 ,,	1321 ,,
P.O.J. 33	,, 23	,,	26-12-26	16.58	13.96	2000 ,,	1353 ,,
,,	,, ,,	,,	27-12-26	16.58	13.96	1710 ,,	1139 ,,
,,	,, ,,	,,	16-1-27	17.43	14.93	975 ,,	658 ,,
,,	,, 35	,,	20-1-27	14.1	12.74	1210 ,,	836 ,,
* ,,	,, 9	,,	24-1-27	17.48	14.69	2705 ,,	1900 ,,
Co. 213	,, 23	,,	9-1-27	17.61	13.82	1053 ,,	711 ,,
,,	,, ,,	,,	21-1-27	16.61	13.67	1715 ,,	1168½ ,,
,,	,, ,,	,,	10-2-27	19.74	15.17	1940 ,,	1240 ,,
,,	,, ,,	,,	3-3-27	20.96	17.04	650 ,,	420 ,,

* Crop attacked by Red Rot.

Percentage of juice to cane.	Weight of rab or 1st. massecuite	Sugar obtained.			Percentage of		
		Weight of 1st sugar.	Weight of 2nd sugar.	Total weight 1st & 2nd sugar.	1st sugar on cane.	2nd sugar on cane.	Total sugar on cane.
9	10	11	12	13	14	15	16
year's crop.							
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.			
63.48	64–12	26–10	9–12	36–6	5.78	2.12	7.9
68.38	222–12	87–14	39–0	126–14	6.05	2.68	8.73
64.56	288–0	130–8	45–0	175–8	7.17	2.47	9.64
65.8	156–0	66–0	29–0	95–0	6.6	2.90	9.50
60.73	208–8	93–4	31–4	124–8	6.01	2.01	8.02
68.84	73–12	29–12	11–2	40–14	5.72	2.13	7.86
67.34	91–0	39–0	14–8	53–8	5.63	2.09	7.73
68.87	288.0	122–14	50–0	172–14	6.40	2.60	9.01
67.75	264–8	116–12	33–4	150–0	5.83	1.68	7.5
66.61	212–0	98–12	0–4	129–0	5.77	1.77	7.54
67.48	140–4	60–2	23–6	83–8	6.17	2.39	8.56
69.09	175–4	80–0	17–10	97–10	6.61	1.45	8.06
70.24	380–8	170–14	59–0	229–14	6.31	2.18	8.49
67.50	147–8	62–8	24–4	86–12	5.93	2.3	8.23
68.13	246–12	103–0	32–10	135–10	6.0	1.91	7.91
63.91	285–0	130–14	25–14	156–12	6.74	1.33	8.07
64.92	97–0	39–12	16–8	56–4	6.11	2.54	8.65

Name of cane variety.	Farm and field no. in which the crop was grown.	Whether plant crop or ratoon crop.	Date of boiling the juice.	Percentage of sucrose		Weight of cane crushed.	Weight of juice obtained.
				in juice	in cane		
1	2	3	4	5	6	7	8
						Plant	**or First**
Co. 221	Nuzhat Afza 23	,,	28-12-26	16.79	13.15	1402 ,,	907 ,,
,,	,, ,,	,,	1-1-27	16.79	13.15	1009 ,,	642 ,,
,,	,, ,,	,,	8-1-27	18.02	14.35	1440 ,,	946 ,,
,,	,, ,,	,,	4-2-27	18.94	14.66	2380 ,,	1558 ,,
,,	,, ,	,,	19-2-27	19.09	14.62	2045 ,,	1340 ,,
@ ,,	,, ,,	,,	20-2-27	22.97	16.27	474 ,,	295 ,,
,,	,, 22	,,	2-3-27	18.94	14.21	1608 ,,	1058 ,,
***Desi Paunda**	Bairasia seed 23	,,	7-1-27	15.74	14.1	887 ,,	624 ,,
Ashy Mauritius	,, 23	,,	25-1-27	17.28	13.93	1304 ,,	946 ,,
		,,	26-1-27	17.47	13.38	950 ,,	640 ,,
Madan Mahal	,,	,,	20-1-27	16.0	13.2	1550 ,,	1106¼ ,,
,, B 247	,, ,,	,,	20-1-27	18.5	13.48	575 ,,	391 ,,
,,	,, ,,	,,	15-2-27	18.16	15.23	90 ,,	59½ ,,
Co. 214	,, 35	,,	25-1-27	17.51	14.19	966 ,,	620 ,,
208 B	,, 23	,,	15-2-27	19.35	16.0	154 ,,	106 ,,
Waxy Red	,, ,,	,,	16-2-27	19.43	15.48	520 ,,	359 ,,
White Transparent	,, ,,	,	16-2-27	17.26	13.66	195 ,,	131 ,,

* Crop attacked by Red Rot.
@ Crop grown without irrigation.

Percentage of juice to cane.	Weight of rab or 1st massecuite	Sugar obtained. Weight of 1st sugar.	Weight of 2nd sugar.	Total weight 1st & 2nd sugar.	Percentage of 1st sugar on cane.	2nd sugar on cane.	Total sugar on cane.
9	10	11	12	13	14	15	16
year's crop.							
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.			
64.69	153–0	68–12	18–12	87–8	4.90	1.33	6.24
63.62	161–0	66–8	24–2	90–10	6.59	2.39	8.98
65.69	187–4	81–6	29–0	110–6	5.65	2.01	7.66
65.46	332–0	155–10	50–4	205–14	6.53	2.11	8.65
65.52	299–0	132–8	35–2	167–10	6.43	1.72	8.19
62.23	72–0	33–4	11–8	44–12	7.01	2.43	9.44
65.78	240–8	99–12	38–12	138–8	6.20	2.40	8.6
70.34	123–8	54–10	18–2	72–12	6.15	2.04	8.20
72.55	200–0	82–12	31–0	113–12	6.34	2.37	8.72
67.37	131–4	61–10	18–14	80–8	6.48	1.98	8.47
71.37	227–4	93–12	27–12	121–8	6.04	1.76	7.80
68.00	89–0	38–10	8–13	47–7	6.71	1.54	8.25
66.11	13–0	5–12	Not determined		6.38	Not determined	
64.18	139–12	55–8	18–4	73–12	5.74	1.88	7.63
68.83	24–8	10–8	Not determined		6.81	Not determined	
69.03	77–4	33–8	11–14	45–6	6.44	2.28	8.72
67.18	27–8	11–8	Not determined.		5.89	Not determined.	

Name of cane variety.	Farm and field no. in which the crop was grown.	Whether plant crop or Ratoon crop.	Date of boiling the juice.	Percentage of sucrose.		Weight of cane crushed.	Weight of juice obtained.
				in juice	in cane		
						Ratoon or	**second**
Yuba (S.39)	N.Bagh 10/2	Ratoon	14-1-27	14.36	11.45	570 lbs	370 lbs
,,	,, ,,	,,	10-2-27	16.33	13.49	1662 ,,	1040 ,,
S. 48	N. Afza 20	,,	6-1-27	18.02	14.48	960 ,,	588 ,,
,,	, 12	,,	18-1-27	Not dete	rmined	1908 ,,	1280 ,,
,,	N. Bagh 5	,,	23-1-27	17.2	13.77	2400 ,,	1600 ,,
,,	N. Afza 20	,,	26-1-27	17.47	13.33	725 ,,	489 ,,
,	N. Bagh 4-5	,,	6-2-27	17.87	14.17	8276 ,,	5545 ,,
,,	,, 4-5	,,	15-2-27	21.46	17.54	3845 ,,	2375 ,,
P.O.J. 33	N. Afza 12	,,	16-12-26	15.83	13.91	1920 ,,	1327 ,,
,,	N. Bagh 8 A	,,	30-12-26	Not deter	mined	1436 ,,	960 ,,
,,	,, ,,	,,	30-12-26	Not deter	mined	960 ,,	639 ,,
,,	,, 8B	,,	12-1-27	16.43	13.41	2001 ,,	1329 ,,
,,	N. Afza 12	,,	19-1-27	17.6	14.24	1920 ,,	1312 ,,
,,	N. Bagh 8B	,,	22-1-27	15.72	12.51	640 ,,	434 ,,
Manjav	N. Afza 12	,,	19-1-27	14.9	12.08	600 ,,	412 ,,
Co 221	,, 23	,,	10-1-27	17.81	14.02	1959 ,,	1239 ,,
						Ind	**igenous**
Kanara	N.Afza 23	Plant	29-1-27	17.11	12.51	400 ,,	220 ,,
Hemja	,, ,,	,,	13-1-27	15.24	11.92	593 ,,	320 ,,
Nasik Khadia	N.Bagh 10/2	Ratoon	12-2-27	Not dete	rmined	2500 ,,	1332 ,,
Munhtora	Intkheri	,,	27-1-27	17.35	11.66	1180 ,,	490 ,,
	,, ,,	,,	21-2-27	Not dete	rmined	2700 ,,	1700 ,,

In the above tests where the total recovery of sugar was lower cane, it is thought that the sucrose left in the second molasses was higher been extracted in part, as third sugar, if the molasses had been reboiled to

Percentage of juice to cane.	Weight of rab or 1st. massecuite	Sugar obtained.			Percentage of		
		Weight of 1st sugar.	Weight of 2nd sugar.	Total weight 1st & 2nd sugar.	1st sugar on cane.	2nd sugar on cane.	Total sugar on cane.
year's cr	**ops.**						
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.			
64.91	71–4	28–12	7–12	36–8	5.04	1.35	6.4
62.57	186–0	71–6	Not dete	rmined	4.29	Not dete	rmined
61.25	137–8	55–2	25–6	80–8	5.74	2.64	8.30
67.08	259–0	99–14	41–12	141–10	5.23	2.18	7.42
66.66	326–4	152–0	47–14	199–14	6.33	2.0	8.33
67.45	108–8	45–8	15–10	61–2	6.27	2.15	8.43
67.00	1266–0	575–8	186–0	761–8	6.96	2.24	9.20
61.78	646–8	272–2	108–8	380–10	7.07	2.82	9.89
69.11	265–8	114–8	41–0	155–8	5.96	2.13	8.09
66.8	192–0	86–0	27–0	113–0	5.99	1.88	7.86
66.56	134–12	54–5	25–3	79–8	5.65	2.62	8.28
66.41	280–8	118–2	46–8	164–10	5.90	2.32	8.22
68.75	284–8	120–0	37–8	157–8	6.25	1.95	8.20
67.81	90–12	34–14	14–2	49–0	5.44	2.21	7.65
68.66	81–4	34–4	8–4	42–8	5.7	1.38	7.08
63.2	278–0	122–12	43–12	166–8	6.26	2.38	8.49
canes.							
55.0	44–0	21–4	7–0	28–4	5.31	1.75	7.06
53.96	72–8	24–4	8–2	30–6	4.08	1.37	5.45
53.28	305–0	129–12	Not dete	rmined	5.18	Not dete	rmined.
41.52	104–0	42–8	,,	,,	3.6	,,	,,
62.96	308–0	130–6	,,	,,	4.82	,,	,,

than might have been expected with reference to the sucrose contents of the than usual, as a result of over-washing the second sugar, and might have make a third massecuite for curing in the centrifugal.

The object of these observations is to impress the reader with the idea that in working on a commercial scale, without the restrictions enjoined by experimental requirements, the owner of the factory may reasonably count on somewhat higher yields of sugar than those indicated in the above statement, and certainly not smaller in any case.

Again it should be remembered that the samples of first sugar resulting from these trials were all of very superior **khand,** of about 98 per cent purity and over, which it was the chief aim to turn out.

If it is desired to produce first sugar of lower polarisation, say 96°, as raw sugars made in several sugar-producing foreign countries usually are, or as the typical **khand** and **chini** now manufactured in Rohelkhand and Benares have been found to be, it would be quite easy to obtain a yield of 10 per cent and over on the cane instead of 8 or 9 under the new system. As a matter of fact, the Indian confectioner who is after all the principal consumer does not need extra white sugar for use in his craft. Indeed, since the free introduction of the brilliant white Java sugar, he has found it necessary to employ foreign yellow dyes to impart artificially the favourite colour fancied by his customers to most of his sweetmeats. Use of dyes is dispensed with, when Indian sugars are used in Indian confectionery. Besides, although the price of extra white Indian sugar, 98 to 99 polarisation, is about a rupee per maund higher than that of the lower grade 96 polarisation, the loss of first sugar which has to be put up with in producing the higher quality, by washing it more thoroughly in the centrifugal, is hardly counterbalanced by the little gain in the price under the present market conditions. It is also an open secret, that up to this time the Indian sugar of lower purity and paler colour commands as a rule a ready sale at a slightly higher price than the Java sugar, superior to it in every respect in the judgment of foreigners. The reason lies not merely in the favour shown to the Indian article on religious or patriotic grounds, but in the peculiar flavour of the sweets made from it which the Indian palate specially prizes. The flavour, as far as can be judged, has its origin in the slight traces of molasses commonly present even in the higher specimens of Indian sugar.

The manufacturer will thus be at liberty to produce such grade or grades as would bring him the highest monetary income, and not necessarily persist in manufacturing the finest article at the expense of his profit in the business. There is always a certain amount of demand in the market for very high grade refined Indian sugars such as **bura** and **qand.** This can be met with by refining inferior grades of sugar, such as those obtained from weak

or carelessly boiled juices or imperfectly cured charges of massecuite in the centrifugal and the hard lumps which have always to be separated in sifting the sugar before bagging.

None of the ratoon crops experimented on had been manured during the year, and none had received more than three waterings, several of them getting only two, and yet the percentage of sugar on cane yielded by them was high enough, pointing to the conclusion that the advantages of taking ratoons from certain varieties suitable for the practice are by no means small.

The plant crops embodied in the trials could not get more than 8 waterings previous to the rainy season, some of them getting only six or seven. Moreover they were by no means manured properly or liberally, as neither were oilcakes available at a reasonable cost in the local market, nor could artificial mineral manures be procured in any quantity. The farmyard manure used was of unknown composition, and the probablity is that it consisted more of rotten vegetable organic matter (litter, house-sweepings, leaves etc.) and ashes than of cattle dung. It is only manure of this quality that is ordinarily available in the neighbouring villages, and even this was not at the author's disposal in quantities sufficient to meet the normal demand of the crops. Most of the fields were undoubtedly green-manured with hemp (Crotalaria Juncea) but the subsequent manurial treatment was confined to applications of farmyard manure in the trenches *only*. The only efficient manure available which could be relied on for its fertilising properties is the poudrette of which there is quite an abundance in the town neighbourhood, but unfortunately all labouring classes at present refuse to handle this valuable agent and the only means of utilising it therefore lies in the employment of **Bhangis** (the professional sweepers) whose number is limited. There is little hope of the use of this material becoming popular, until the prejudice against handling the manure is removed, and the cost of its transport materially reduced by replacing the expensive bullock carts with the motor lorry. This should be done where conditions similar to those in Bhopal exist.

It will thus be clear, that the plant crops under discussion were by no means raised under the best conditions of intensive agriculture and therefore in every case the total sugar actually recovered should not be regarded as the highest possible under the new system.

Looking at the figures of the yield of white sugar from ratoon canes of the imported varieties it will be seen from the foregoing statement that Yuba has, as in previous years, proved a very poor yielder and it can now be safely declared that the variety is unsuitable for cultivation when the object is to produce white sugar.

One of the author's correspondents in another part of the country has reported that there it is so susceptible to red rot that he was compelled to abandon its cultivation. It may develop the disease in Malwa too, and it is therefore not desirable to introduce this cane in Central India.

Interested readers, specially those who are working or intend to work under the new system, are invited to study the figures for themselves in order not only to see what the possibilities for the production of white sugar under the new open pan system are, but to mark how the yields vary from field to field according to the variety, the stage of the season, the degree of ripeness and the richness of the cane.

It will be seen that in Malwa, a very high yield of white sugar must not be expected from the cane, if the crushing is started in December as is the practice with the manufacturer of **gur** in the country. In January an average outturn of about 7 to 7.5 per cent of total sugar from good cane may reasonably be expected, provided the massecuite is boiled properly. It is in February and March, when the cane has attained maturity and the richness and purity of the juices have reached their maximum limit, that the higher yields of 8.5 to 9 per cent and over may be obtained.

Different (better) results with regard to yield may however be obtained in the earlier stages of the season, if the crop to be dealt with is a ratoon one which usually ripens earlier than the plant crop.

If the crop has been attacked with red rot, which usually does not become manifest until January, the sooner it is cut and converted into sugar the less will be the loss in the business. Two of of the crops shown in the above statement were attacked with the disease, but as a result of their manipulation as soon as the disease was noticed, the yield of sugar in both cases was not unsatisfactory, although the quality of the massecuite and of the resulting sugar was naturally far below the mark. These sugars fetched in the market about a rupee per maund less than those of the normal quality. Had the crop been allowed to stand longer in the fields, the results would have been worse, probably disasterous.

Crops attacked by the Chilo in the hot weather recover slowly during the rains and ordinarily do not attain maturity till March. It would therefore be well to keep them standing till the later part of the crushing season and to handle them when they are fully ripe. Generally such crops do not mature fully even in March, and have to be crushed before they have had time to develop the maximum quantity of sucrose in them, but they can not be kept on

indefinitely and must be manipulated towards the end of the season. If such canes as have formed internodes, but have not grown to the normal height, are picked out and used for seed or crushing, the remainder will usually yield a finer ratoon than the mother plant crop.

It should be recognised, that in experiments which have to be carried out necessarily with small quantities of the raw material available, as was the case in the author's programme of operations, losses of no insignificant character are bound to occur in manipulation of the various products, and when making calculations of percentage outturns from the data obtained, the losses must multiply. For instance, when the boiling of the juice is finished, a certain quantity of the massecuite is inevitably left sticking to the boiling pan and cannot be recovered. If the boiling is carried on, say for three hours, the loss of sugar on this account would be the same as when it is kept up for a whole working day. Similarly the wastage of the massecuite in the crystallisers would be less if they were large vessels such as tanks tnan if it had been potted in kerosene tins or earthen **kalsis.** The losses in the pug-mill, the centrifugal and on **pata** (the crushing floor) will also be less if the quntities of massecuite and sugar manipulated are large, and the charges put into the cage are of the maximum weight the centrifugal is capable of spinning at a time, or as near it as convenient.

Ratoon crops of other imported kinds have given very satisfactory returns.

All varieties of indigenous origin have yielded very poor results except Kinara, an Indian cane imported from Rohelkhand, which has done best among them, though none of them have approached the yield of the seedling canes.

CHAPTER. XIII.

Manufacture of Gur on a commercial scale.

The new Bhopal **bel** described in the foregoing chapter though designed primarily for production of **rab** has been found equally suitable for manufacture of highly prized and cleanly made **gur** which should be the ideal of the Indian capitalist desirous of working on a scale wider than the cottage industry limits.

With trebled outturns of cane in weight ensured, by the Coimbatore crosses and exotics in Upper India, and recently under the soil and climatic conditions of Malwa, and with every expectation of a rapid and continuous extension of the cultivation of these varieties in almost all parts of India, the question how this increased outturn is to be manipulated on the manufacture side, with the existing cattle power available for crushing the cane, forces itself on the attention of all concerned in the advancement of Indian agriculture. Immediate increase in cattle power being unthinkable, the only solution of the problem seems to lie in the substitution of mechanical means for crushing the cane, the cattle and man power so liberated being rendered available for utilisation towards extending cane cultivation and securing other agricultural objects which can best be gained by employing such power only. The question therefore at once becomes one of all-India importance and should be treated as such. It is indeed of such moment that the Indian Sugar Committee have thought it fit to devote a considerable portion of chapter XVIII of their Report to a discussion of the subject and have also referred to it in chapter XVII. The question is of special importance for Malwa where manufacture of **gur** is at present a highly remunerative commercial proposition but where, on account of defects in the system of manufacture, the cost of production is inordinately high and the quality of the product very inferior. So long as the existing high prices of **gur** rule in Central India, it should be a highly paying business for the local agriculturist to grow the high-yielding cane varieties on a large scale where agricultural conditions are favourable for production of **gur** in preference to any other saccharine product. For many years to come the capitalist cane-grower of this part of India whose sole object is to get the largest monetary return with the least trouble need not concern himself with the idea of producing white sugar. Economic production of the latter will demand his serious attention inevitably when there is a marked fall in the prices of **gur** which is bound to follow, in competition with the cheaper and better **gur** of Upper India, though only gradually. In places where large compact areas of sugarcane are at present grown, but **gur** is manufactured on un-

sound lines, such for example, as in the **parganas** of Ichhawar and Jawar in the Bhopal territory, it will be advisable to set up a small power-crusher in conjunction with a **bel** of the new design in order to crush the cane for a whole village or a number of villages and convert the juice into **gur.** This may be done in other Central India States, either on a suitably devised co-operative or hire-purchase system or merely as a demonstrative measure at the start.

The same recommendation will apply with greater force to other parts of India where cane is more largely cultivated with the ultimate object of producing **gur.** The question of power-crushing is thus of universal interest for the Indian Sugar Industry.

The Indian Sugar Committee have remarked in para 292 of their Report that in their view "there is no agricultural operation to which power-driven machinery can be more effectively applied than for crushing cane." The Committee also "regard the introduction of the small power plant as indispensable to the development of the **gur** industry." A proper power-crusher being an immediate and pressing necessity, it is essential to import or manufacture one in India which should be as efficient at least as the best 3-roller mills now in general use in the country, and if found satisfactory by actual working to bring it to the notice of the agricultural public. Power-mills hitherto made in India do not seem to have impressed any one favourably. Those of the Indian make with 8 inches rollers have been found to extract only 56.2 parts of juice from 100 parts of cane against 66.8 parts extracted from the same cane by the 3-roller mills of the same size, but of the best make, worked by bullocks (vide para 298 of the Indian Sugar Committee's Report) and the Committee have therefore been obliged to declare it as their considered opinion that the above type of the power mill "is inferior to the bullock mill where the latter is working under the best conditions." With regard to these types they remarked that there was "considerable room for improvement in them" and that "a most desirable improvement in them would be the addition of an extra pair of splitting roll crushers to the mill which by adding two extra rollers, at a comparatively small additional cost would virtually convert it into a five roller mill and enable it to give a higher extraction." The Committee directed the special attention of the Engineering section of the Agricultural departments in all Provinces to the question of designing a small power-mill on these lines. The writer of these pages is not aware whether any such mill having the requisite efficiency has hitherto been worked out by any of the Provincial Departments in India. He hopes that skilled talent is busy somewhere in solving the problem and that it will not take long before the solution becomes a reality.

A power-mill of Indian manufacture $16'' \times 24''$ was tried some years ago in Bhopal but is said to have yielded only 56 to 60 per cent of juice from the cane. An American Power-Crusher largely advertised during the past few years was tested recently at one of the Bhopal Farms but it yielded a satisfactory extraction only when the cane was passed twice through the mill which halved its working capacity.

In parts and on the borders of Rohelkhand where power-mills $8'' \times 8''$ made in India are being used, the extraction from seedling canes of good average quality has been found by actual trials to vary from 60 to 63.8 per cent of the weight of cane crushed. A mill of this type worked with a 7-9 H.P. oil engine is illustrated opposite page 20 of "Notes on improved methods of cane cultivation" published by the Department of Agriculture, U. P. in 1919, and in one place where a mill having rollers $14'' \times 10''$ is employed as much as 65% is said to have been obtained in the shape of juice from the cane.

Considering that from 68 to 75 per cent of juice is extracted at the Bhopal Farms from seedlings and exotics, when good 3-roller mills worked by bullocks are used, the author is unable, so far, on the basis of practical experience to point out a power-mill which would approach the local bullock mills in efficiency, far less beat them.

It has been reported that a power-crusher made by Messrs Manlove & Alliot of Nottingham, England, which could be landed in Central and Upper India at a cost of about Rs. 7000/- has been working satisfactorily at one of Indian Sugar Farms for several years extracting 75 per cent of juice and more from thick canes. The author has had no opportunity of seeing this machine at work.

Speaking of Messrs Blair, Campbell and McLean's Sugar-making plant in paras 280 and 281 of their Report, the Indian Sugar Committee have remarked that "the most striking and novel features of the plant is the mill which is capable of giving a very high extraction. In 1917-18 as much as 83.11 per cent of the sugar in the cane was reported to have been extracted on the average throughout the season." The cost of this mill is not known at present. The same authority has told us in para 273 of the Report that "a thoroughly up-to-date milling plant can to-day be counted upon to extract in the form of juice as much as 96% of the sugar actually present in the cane." A fully efficient crushing plant is thus obviously the first imperative necessity if increased outturns of **gur** are to be obtained from the cane.

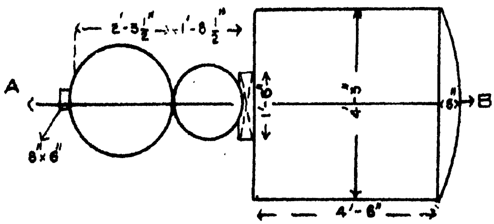
ILLUSTRATION NO. VII

"THE AUXILIARY BEL"

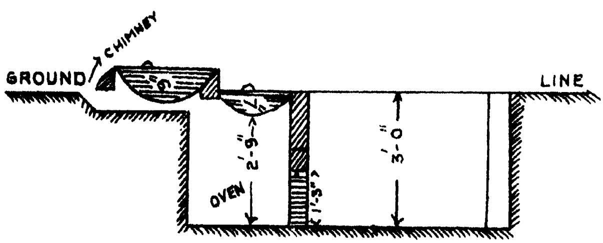
PANS AND FURNACE FOR CONCENTRATING THIN BOILED RAB INTO GUR WHEN BOILING ON A COMMERCIAL SCALE

— Scale 4 ft. = 1 in. —

— PLAN —

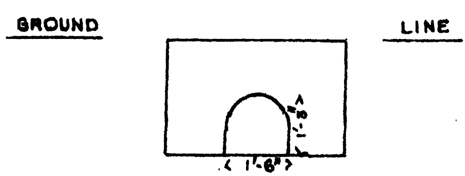


SECTION ON A. B.



A third pan of the samo size as the second may be set up behind the second & between the chimney and the second pan; if the amount of gur or massecuite (as the case may be) to be boiled during the day is to be larger than can be boiled by a system of two pans.

FRONT ELEVATION



In the absence of definite information regarding the relative efficiency and the prices of the various types manufactured by British and American Firms, the author feels justified in bringing Messrs Blair, Campbell and McLeans mill to the notice of those who may decide to instal a power plant, considering that that mill has not only had unqualified approval of such a distinguished authority as the Indian Sugar Committee but has been actually tested in Upper India with remarkable success.

As has been stated at the commencement of this chapter, the new Bhopal **bel** with its improved furnace would suit admirably for making **gur** on a large scale. The number of **bels** to be set up will depend upon the quantity of juice available from the mill used, one set of pans being sufficient to boil about 75 maunds of juice into **gur** during the ordinary working day.

The high quality of the finished product is secured by the rapid concentration of thoroughly clear clarified liquor in small quantities but in quick succession and at short intervals.

Care should be taken to stop the feeding of the furnace as soon as the mass in the **Parchha** has nearly reached the final stage of boiling, and to replenish the pan while there is still some boiled material left in it which could, but should not be transferred to the **Chak.**

Under this arrangement however it will be rather difficult, unless the boiler is a most experienced expert, to maintain the highest quality throughout the day. Some of the specimens produced will be better than others, while some will be found to have become more or less red in colour through inadvertency. If therefore, the object is to obtain a very superior quality and uniformity in colour right through, the alternative will be to set up an "auxiliary **bel**" consisting of two or three shallow thick-bottomed iron **Parchhas** one larger than the other on a separate furnace as illustrated opposite this page (vide Illustration no. VII). The larger **parchha** should remain permanently fixed on the furnace while the smaller should be so placed as to be easily removable from the oven when wanted. Where this arrangement is provided, the clarification of the juice and the preliminary concentration of the liquor and the syrup should be effected in the standard Bhopal **bel** (Illustration no. V), until a sort of **rab** of thin consistency is ready in the **parchha.** When the temperature of mass in this pan is about 107°C or 108°C, it should be ladled out in a kerosene tin to be transferred for further concentration to the second smaller **bel** of two or three pans just mentioned, its place in the said pan being at once occupied by semi-concentrated syrup ladled from the second pan (**Manjha**) of the standard **bel.** If, or when, the thin **rab,**

so sent to the second bel, is in excess of the quantity the latter is capable of holding at a time, the excess amount should be kept warm in the tin or tins or in a separate pan near the fire, so as to prevent crystallisation until the time arrives for pouring it into the auxiliary **bel.** By concentrating the thin **rab** into **gur** in the second **bel** the quality in general, and the colour in particular are, very effectively controlled, a very fascinating final product being obtained. As the concentration of each charge in the auxiliary **bel** is completed the firing should cease, the pan should be brought down from the oven and the contents after being stirred with the wooden **Ghotna** spread out on the **Chak.** The empty **parchha** should again be placed on the oven and at once charged with the liquid ladled in from the second pan. Under this arrangement the standard and the auxiliary **bels** together should be able to convert about 90 to 95 Mds. of juice into **gur** during the working day.

We have now to consider the economic aspect of operations involving the use of a power plant for crushing the cane and of improved furnaces of the above types for making the **gur.**

For estimating the cost of crushing in Malwa we base our calculations on the actual figures obtained from an installation working in a Rohelkhand district where a power-crusher of Indian manufacture having rollers 14″×10″ is worked with a 17 B.H.P. Crude Oil Engine. The capacity of the crusher in terms of cane crushed per hour on the average is 35 standard Mds. though with proper care and attention it is said to crush upto 37.5 Mds., the extraction with medium canes being 65%. Details of the daily expenses are noted below:—

WORKING THE ENGINE.	Rs.	as.	p.
2 bottles of kerosene oil ...	0	5	0
6 gallons of crude oil ...	3	12	0
1½ lbs. of cylinder oil ...	0	5	3
2 **chhataks** of cotton waste ...	0	1	3
1 Driver (pay) ...	1	0	0
1 Lubrication ...	0	5	0
10% depreciation on Rs. 500/- the cost of the engine calculated for 90 days. ...	4	0	0
Total ...	9	12	6

	Rs. as. p.
2 cane-feeders	0 12 0
2 females for helping the above..	0 6 0
2 boys for removing the bagasse	0 6 0
Grease 1 **chhatak**	0 1 0
10% depreciation on Rs. 1700/- the cost of crusher calculated for 90 days.	1 14 0
Total ..	3 7 0

Total cost of working the engine and the crusher .. 13 3 6

Working on the average 11.5 hours a day, as was done with similar plants in Madras (vide para 294 of the Indian Sugar Committee's Report) the quantity of cane crushed with the plant under consideration will be about 400 Mds. per day (crushing 35 Mds per hour). The cost of crushing one Md. of cane thus comes to 6.3 pies.

The cost of making **gur** from the juice will be:—

(A) If no auxiliary **bel** is used:—

	Rs. as. p
Cost of crushing 115 Mds. of cane at 6.3 pies per Md.	3 13 0
Boiling 75 *Mds of juice into **gur** (vide details on pages 131 & 132 chapter XI) ..	6 4 9
Total ..	10 1 9

Outturn, 14¼ Mds. **gur** (19% of the juice)

$$\text{Cost per Md} = \frac{\text{Rs. 10-1-9}}{\text{14.25 Mds of } \textbf{gur}} = \text{11.4 annas per md. of } \textbf{gur.}$$

$$\text{or } \frac{\text{Rs. 10-1-9}}{\text{115 Mds. of Cane.}} = \text{1.4 annas per md. of Cane}$$

* The improved standard **bel** of Bhopal when boiling juice for **gur** will boil conveniently about 75 mds. of juice into **gur** if unaided by the auxiliary **bel** instead of 90 mds. of juice when boiling the latter for **rab**.

(B)	If an auxiliary **bel** is used so as to produce very superior **gur.**			
	Running the standard Bhopal **bel** for one day (vide details on pages 131 & 132 chapter XI) for converting the juice into thin **rab.**	6	4	9
	Extra labour and fuel required for working the auxiliary **bel** to make **gur** from the **rab.**	2	8	0
	Total ...	8	12	9

The Bhopal **bel** in conjunction with an auxiliary **bel** is capable of working 90 Mds of juice a day into **gur** which is equivalent to 138 Mds of cane (65% extraction).

The total cost of crushing with power and making **gur** from the juice in improved furnaces is calculated thus :—

Crushing 138 Mds of cane at 6.3 pies per Md.	4	8	0
Boiling 90 Mds of juice into **gur.** ...	8	12	9
Total ...	13	4	9

Outturn of **gur,** 17Mds (19% of the juice). Therefore the total cost of manufacture of **gur** of **very superior quality** from the cane will be 12.5 annas per Md. of **gur** or 1.54 annas per Md. of cane. If the auxiliary **bel** is dispensed with and **gur** of average good quality prepared (though even that would excel the specimens now produced in Malwa) the cost of boiling will be reduced to 11.4 annas per Md. of **gur** and 1.4 annas per Md. of cane. The cost will go further down if a power-mill yielding a higher extraction is employed.

So far as the cost of manufacture is concerned, the economy resulting from the employment of the above process in preference to the bullock-mill for crushing and small furnaces described before for boiling the **gur,** is so obvious that it is hardly necessary to give reasons emphasising the desirability of adopting the methods discussed above where-ever it is possible to do so. In chapter XVIII of the Indian Sugar Committee's Report dealing with the manufacture of **gur** it has already been declared by the committee that "the first essential for improvement is the introduction of power -crushing with small plant." A perusal of paras 294 and 295 of the Report will show that power-crushing in conjunction with

improved furnace has been tried in certain districts of Madras and in different parts of Mysore State, but did not prove a financial success. In the Madras experiments of which accurate figures have been quoted by the Committee, the cost of converting the cane into **gur** varied from Rs. 3-4-9. to Rs. 3-8-0 per **pothi** (260lbs.) or Rs. 1.04 to Rs. 1.6 per standard Md, of **gur** produced.

The Bhopal figures ranging from 11.4 to 12.5 annas per Md. of **gur** as mentioned above are distinctly lower than those of Madras. As the cost of power-milling in Madras cannot differ widely from that in Bhopal or any other part of India, the author of these pages is led to the conclusion that in the Madras experiments the cost of production rose high owing to the use, with each mill of too many furnaces, each requiring presumably somewhat expensive skilled labour. In the opinion of the Indian Sugar Committee power-crushing for manufacture of **gur** is not likely to receive favour, until the crushing and the boiling plant is able to turn out **gur** at not more than 1.8 annas in Madras and 2 annas in Upper India per Md. of cane crushed (Recommendation No. 10 pages 290 of the Report). Indeed they found in Madras that "the cultivator will not bring his cane to a power installation if he is charged a higher rate than 1.8 annas per Md. of cane for its conversion into **gur.**"

The Bhopal experiments as stated above have shown that it is possible to produce **gur** at a cost varying from 1.4 to 1.54 annas per Md. of cane not as a result of any mechanical changes in the crushing mill but as that of improvements in the boiling pans and the furnace construction. This great problem would seem thus to have very nearly approached solution, if not solved already. The author* has not yet had an opportunity of working in Bhopal with a power plant, figures for which are fairly constant all over India but he has had 4 season's practical experience in boiling and it is in the reduced cost of the latter and the superfine quality of the **gur** that any economic advantage he may have gained lies.

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* Since this book went to the press a power crusher was tried in Bhopal (vide appendix A)

CHAPTER. XIV.

The Centrifugal Machine.

The Centrifugal Machine is an old contrivance for separating solids from liquids and is largely used in Europe and America in many branches of the chemical industry of those countries. It is also extensively used in the laundry and dry cleaning trades because of the ease with which it is possible to remove moisture from a material like cloth in order to dry the latter. The Centrifugal Machine was first introduced into the Sugar Industry about 75 years ago by Dubranfaut, and it is now indispensable wherever sugar is made by modern methods, for such operations as the extraction of molasses from raw sugar, and the refining of the massecuite. The principal advantage of the centrifugal (extractor type) machine lies in the fact that solids can be completely freed of a contaminating liquid in one operation. There are many different types of centrifugal machines made for different purposes and the original particular names, such as "Hydro-Extractor" may be loosely used and thereby cause confusion, but the centrifugal machine or the "centrifuge" to which these pages refer is the extractor type of machine which consists essentially of a perforated drum or basket made to revolve at high speed inside an outer steel casing which serves to catch the liquid material thrown out from the basket as a result of the centrifugal force developed by the spin. The basket may be of perforated metal or of wire construction suitably strengthened and lined with a fine wire cloth. The most suitable copper gauze lining for dealing with open pan sugar is the 70 mesh which has 4900 apertures per square inch. Whenever contact is made with sugar, while it is spinning at full speed, the material employed should be copper. The principle upon which the machine works is thus very simple and the procedure is as follows :—**Rab,** which in India corresponds to the massecuite of the refinery, and is the product of the final boiling of the juice is a magma of sugar crystals and a thick, more or less sticky, solution of sugar and of those bodies present in the juice which have not been eliminated by the clarification processes. This material is poured into the basket of the centrifugal machine, and is thrown against the perforated copper lining of the basket when the machine is set in motion. The sugar crystals are retained in the basket while the molasses escapes through the perforations, is caught by the outer casing of the machine and collected in a receptacle conveniently placed below.

The power may be supplied to the machine in a variety of ways, through a system of pulleys and belts or by toothed wheels. If the machine is small, hand power may be sufficient or bullock

18-in. Self-balancing Centrifuge

(Under-driven Type)

DRIVEN BY HAND POWER.

"HANDELOX" MACHINE—Type 12.

MADE BY

THOMAS BROADBENT & SONS, LIMITED,

HUDDERSFIELD, ENGLAND.

power may be applied with convenient gear, and of course the machine can be driven by water pressure, steam, electricity or whatever type of power is available. It is only a question of arrangement.

There are two main types of the machine viz., the fixed bearing under-driven pattern (**phirkiwali**) which is the older of the two, and the suspended pattern (**chhinkewali**) which is said to have been introduced by David Weston in the Hawaiian Islands in 1852. Machines of the last mentioned pattern are still called centrifuges of the Weston type. It is also possible to have bottom discharge from the basket for the dried material, which is a great convenience as compared with scraping and lifting the sugar charge from the basket by hand. The suspended pattern machine also consumes less power than other types, the weight being taken on a ball race, and the bearings are very flexible. In the author's experience, however, the under-driven type of machine illustrated opposite this page has produced the most brilliant and whitest sugar crystals, working on **rab** produced by the open pan system of boiling as practised in India. The machines used hitherto in the Indian indigenous factories have been either a small experimental type with a basket 18 inches diameter and a depth of 9 inches, and driven by hand, or, as in Mysore, with bullock power, or a larger machine of 30 inches diameter and 12 inches deep, driven usually by steam. The hand-power machine that has given most successful results in the long series of trials made by the author and which is used by some sugar manufacturers in different parts of India, is the 18 inches under-driven "Handelox" machine made by Messrs Thomas Broadbent & Sons Ltd. of Huddersfield, England, and which is illustrated here as type no. 12. The author has been courteously permitted by that firm to produce from one of their leaflets the following table of reference and instructions for attending and oiling their under-driven type machines and he has done so mainly because of the lamentable dearth of mechanics in Indian villages, for it is hoped that the machines will gradually be adopted in the villages to help the cottage sugar industry in India. Detailed information regarding the various parts constituting the machine will therefore be welcome to the Indian owner, not only that he may acquire an intimate knowledge of the functions of each part, but also that he may familiarise himself with the trade names of each part and so make himself understood by the makers when the necessity for a replacement arises. The average village blacksmith (**lohar**) is intelligent enough to grasp matters with the drawing of a machine as well as with the real machine before him, but sad disappointments have sometimes to be faced in outlying places for no fault of the machine, but because the object and *care* of the various parts were insufficiently understood by the attendant.

A diagram showing a cross-section of the arrangement in Messrs Broadbent's self-balancing under-driven centrifugal will be found facing this page.

Description of the various parts marked in the diagram

B. Stamped Steel cover to outer casing. This is a turned fit and can be lifted off by tapping gently round the outside with a mallet.

C. Steel safety outer casing.

D. Revolving basket. This can be removed by taking off the steel cover (**B**) and then unscrewing the nut on the top of the spindle.

E. Centre spindle.

F. Thoroughfare for oil to chamber (**H**) into top bearing.

G. Top bearing with spiral oil groove in phosphor bronze lining.

H. Oil chamber above top bearing.

J. Tube for conducting oil from chamber (**K**) into chamber(**H**)

K. Oil chamber formed as part of the driven pulley. When the spindle revolves, the centrifugal force puts the oil under pressure and compels it to rise through tube (**J**) to chamber **H**; from there it gravitates through a spiral groove in the top bearing into the chamber case, and thus keeps up a constant circulation of oil. The tube (**J**) should be set so as to nearly touch the side of chamber (**K**). In order to see that the oil is circulating properly, it is necessary to take out the basket and run the spindle; if the chamber (**K**) is then charged with oil and tube (**J**) properly set, the oil will be seen flowing up the tube into chamber (**H**).

L. Casting containing spring boxes.

M. Spring boxes.

N. Set screws for holding back the spring boxes when it is required to take out the spindle and bush.

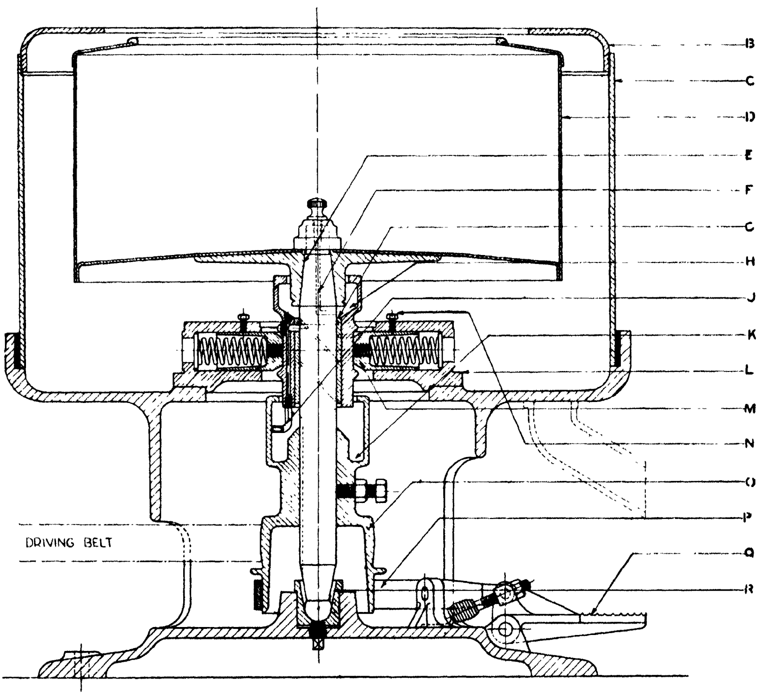
Note. To take out the top bearing, the spring boxes are compressed by the long screw supplied with the machine, which is inserted through the end of the casting **L** each box is compressed separately, and then locked fast by the set

DIAGRAM

SHOWING CROSS-SECTION OF A "BROADBENT"

Self-balancing Centrifuge

(Under-driven Type).

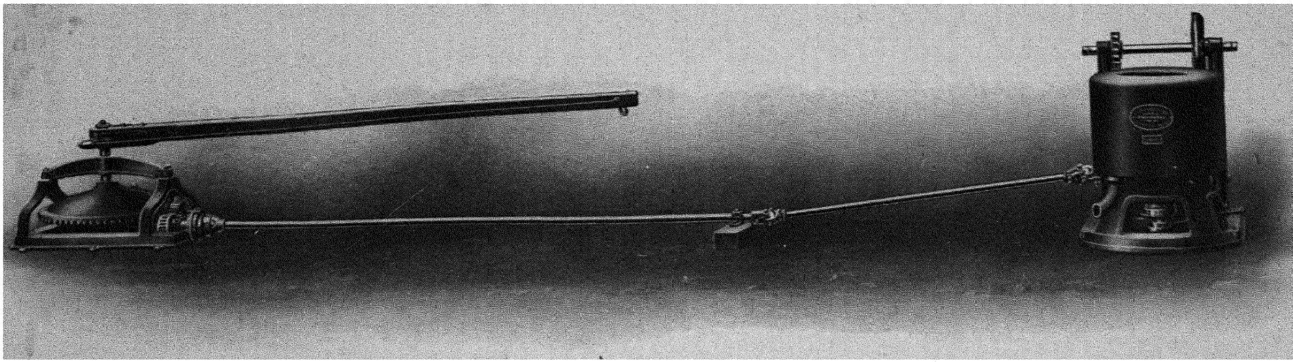


For reference to the various parts see text matter on other page.

18-in. Self-balancing Centrifuge

(Under-driven Type)

DRIVEN BY BULLOCK POWER.



"BULDISOCK" MACHINE—Type 19.

MADE BY
THOMAS BROADBENT & SONS, LIMITED,
HUDDERSFIELD, ENGLAND.

screw (**N**). The tube (**J**) has then to be turned slightly towards the spindle by the insertion of a steel rule into the chamber (**K**). The bearing then can be withdrawn. In replacing this bearing care must be taken to turn the tube again outwards.

O. Driving pulley and brakedrum combined.

P. Brake band with "Ferodo" lining.

Q. Foot lever for brake.

R. Phosphor bronze footstep bearing.

The same machine arranged for work with bullock power is illustrated (type 19) opposite this page.

The author has never tested type 19 but it is highly recommended by the makers in whose catalogue it is shown. The cattle gear attached to the machine could no doubt be manufactured in India, but it would be better and possibly cheaper to get it out from England. If by actual trials, this arrangement produced as good a sugar as with the use of hand power, type no. 19 stands every chance of replacing type no. 12, because bullock power is far more convenient for working everywhere in India, and for working hand power machines labourers having good physique have to be selected and specially trained before they become efficient, and in any case, hand labour is not easy to get in Malwa.

A small hand-power belt-driven machine of the suspended type having a basket of 18″ diameter (Broadbent's type 16) has, as the result of experiments and demonstrations carried out in the United Provinces about 17 years ago, undoubtedly gained favour with the sugar makers of Rohelkhand where it is used in fairly large numbers and in preference to the "Handelox" on account of a markedly increased output with less expense of labour though at a small sacrifice in the quality of the sugar. It is really this machine that is responsible for the rapid replacement of the **Khanchi** by the centrifugal system which has taken place in the famous sugar-making tract of Rohelkhand. An illustration of it is shown opposite next page with a cross-section showing the arrangement of the spindle, the flexible bearing ball race, the drum and the bottom discharge.

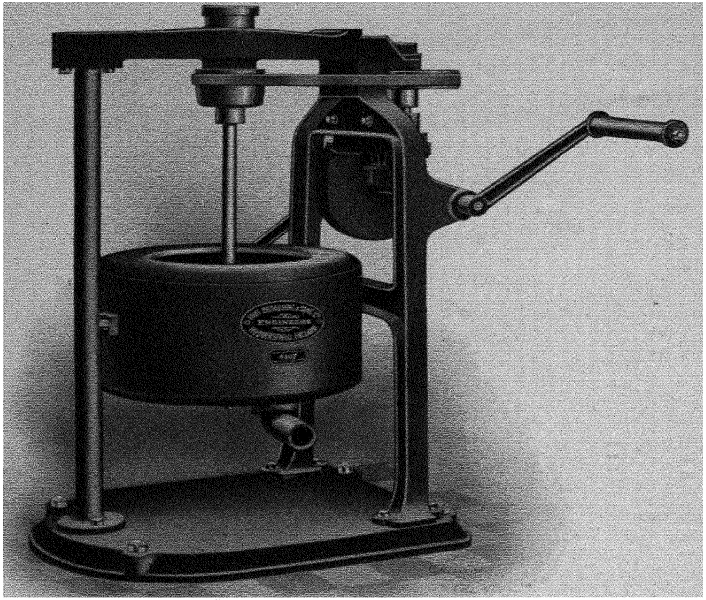
The latest Weston type manual power centrifugal of 14″ and 18″ diameter (type 16A) brought out by Messrs Broadbent and Sons and successfully tested in Bhopal is illustrated opposite page 189. This is a gear-driven machine having a steel frame and perforated black steel cage lined with No. 8 steel gauze, No. 70 copper twill and No. 26/30 copper twill gauze with a central bottom discharge, power being supplied by an arrangement of toothed wheels.

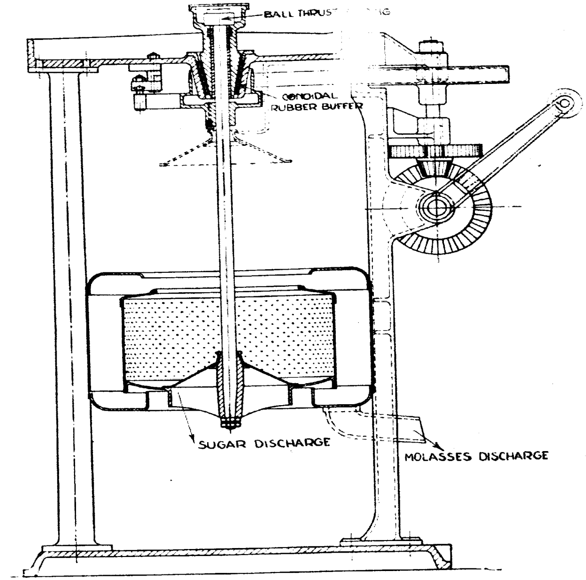
The 14" and the 18" gear-driven machines of the last mentioned type have given every satisfaction. They seem to be suitable for the Indian manufacturer, and may prove more so than type 16 (Belt-driven). The same gear-driven type worked by power is illustrated opposite page 190.

The machines described above would in a day of 8 or 9 hours comfortably work up 10 to 15 standard maunds of first **rab** into white sugar, having a polarisation of about 97° or 98° according to their size and capacity; and provided that the copper mesh is of the right size and the speed of the machine sufficient and uniform, from 4½ to 7 standard maunds of white first sugar according to the richness of the cane. These figures represent the yield of about 1/6th of an acre of cane of one of the selected varieties. It would thus be reasonable to expect that one machine would suffice in the season for a plantation of 15 acres at least. At present no single village cultivator can command such a large area by himself, but a group of cultivators in a village might club together to buy a machine or, where a co-operative society exists, such a machine could be set up by the society and worked under a co-operative arrangement, not difficult to devise. Failing other arrangements, the State could hire out machines in charge of a trained **mistri** to a recognised body of cultivators: but when larger areas than 15 acres or so have to be dealt with, as may well be the case with the probable increase in the cultivation of selected canes, it would be necessary to use power-driven machines instead of hand or bullock-driven type. Then also it would be necessary not only to procure larger sizes of centrifugal machines and the corresponding engine and boiler, but also a pug-mill for breaking the **rab** so as to prepare a homogeneous material with which to feed the centrifugal. There are several pug-mills on the British market, but to give the reader, not familiar with the machine, an idea of it, a diagram of a hand-operated pug-mill sold by Messrs Broadbent & Sons is given opposite page 191.

The mill mentioned above (though not tested at Bhopal) is said to be of a strong construction and is fitted with two combs and one pugging drum and teeth of which are cast on loose rings and can readily be replaced in the event of breakage due to any foreign substance being introduced into the mill. It is arranged to be operated by hand or driven by means of a belt from shafting. The size illustrated is sufficiently large to prepare material for two 30" size or six 18" size centrifugals, and it can either be supplied separately or combined with a power-driven centrifugal machine. A large number of these pug-mills are working in India some of them having given continuous service since 1910.

18-in. Over-driven Centrifuge (DRIVEN BY HAND POWER).



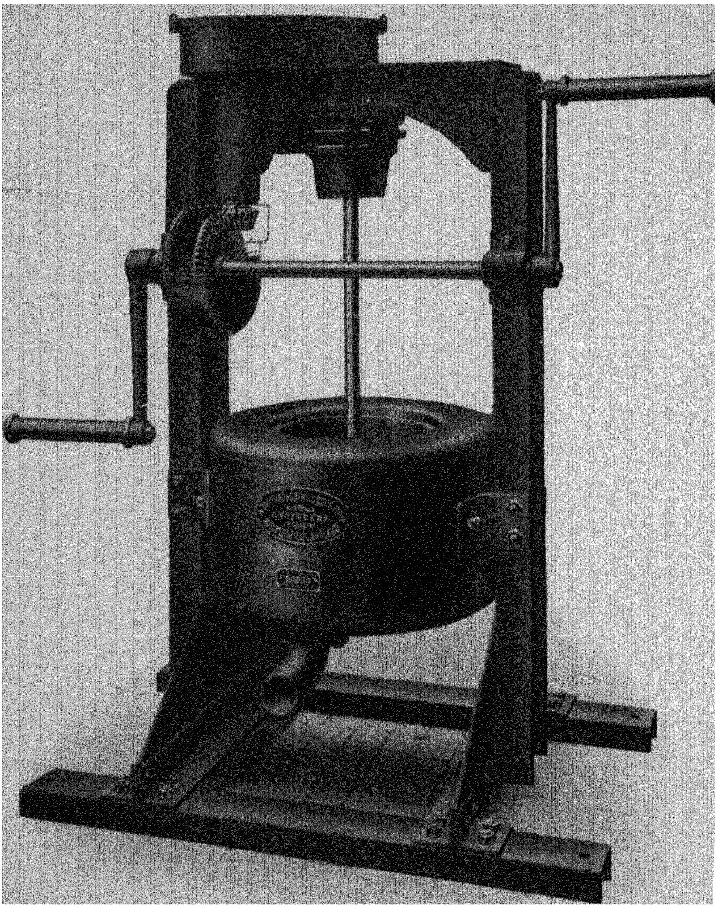


"HESTOGAL" MACHINE—Type 16.

MADE BY THOMAS BROADBENT & SONS, LIMITED, HUDDERSFIELD, ENGLAND.

Hand Power Centrifugal

With Central Bottom Discharge.



Type No. 16A.

Made by

THOMAS BROADBENT & SONS, LTD.,

HUDDERSFIELD.

The selection of a **perfectly** suitable type of power centrifugal for dealing with Indian **rab** has passed the experimental stage, Messrs Broadbent & Sons having substantially solved the problem as a result of persistent efforts to meet all the requirements of the Indian massecuite. Although the author, because of his long practical experience with Broadbents' "Handelox," is firm in his belief that, when the main object is to produce a very high grade of Indian sugar, any under-driven machine is preferable to any machine of the suspended pattern for work in India, yet he is not able at this stage to recommend with confidence any large power-driven centrifugal machine of the "Handelox" type because no such machines have hitherto been used successfully in India within the author's knowledge. Messrs Broadbent & Sons have supplied Weston type centrifugals of 26" diameter combined with an engine and a pug-mill. Although the author has not had the opportunity of trying this set at Bhopal, a pupil of his who has worked the machine for a whole season has reported very favourably on it, an average sample of his sugar having obtained the highest commendation in an agricultural show where numerous specimens of Indian sugar produced by various manufacturers under different methods, had been exhibited. It deals conveniently with about 40 maunds of **rab** in a day of 10 hours at a cost of about 5 annas per maund including depreciation and interest.

If a suspended over-driven type power machine is used, there are plenty to choose from, such as Broadbent's type no. 20 which is similar to a 30" machine which was tested in Rohelkhand and worked on commercial lines with success in that and other parts of Upper India, such as Bareilly, Shahjahanpur and Meerut.

This type of 30" machine has now been superseded by a much improved design known as type 20 mentioned above. An illustration of Broadbent's machine type 20 will be found opposite page 200. The arrangement illustrated can be made to suit a machine of any standard size.

Provided the mesh is of the right grade, a 30" machine of this pattern should work about 60 maunds of **rab** in the course of a working day of 10 hours. During a season the machine should prove sufficient to work off the **rab** outturn of 80 to 100 acres of cane according to the quality of the crop into first sugar and could also deal with the second or molasses **rab** during the following hot weather months.

If a still larger cane area has to be served a battery of two such machines as illustrated opposite page 201 should be employed in order to deal conveniently with about 200 acres of cane in the course of the season. This battery is one of the several recently brought out by the makers for use in Rohelkhand.

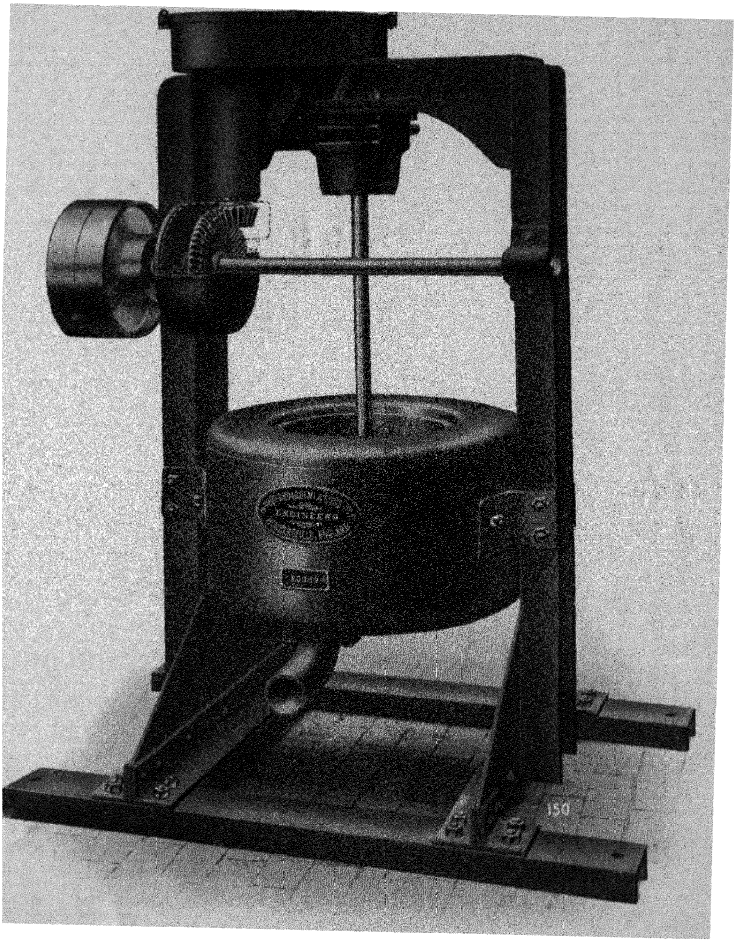
A similar battery was very successfully demonstrated at the Allahabad Exhibition of 1910/11 and was purchased and used on commercial lines by a wealthy land owner. The arrangement is therefore not new to Upper India.

Separation of molasses. The purging and curing of sugar.

If the cane were rich and boiling properly done, the **rab** should be fairly hard and much molasses will not be found in the mass. There will be more molasses if the **rab,** when potted, was of a thin consistency. In the latter case sufficient time should always be given to complete the crystallisation. In both cases it would be well, if working on a small scale, for example with a 14″ diameter centrifugal without the use of a pugmill, to spread the massecuite when taken out of the pot on a rough filter, made by fastening a piece of woollen blanket or coarse cloth firmly to the upper rim of a pan or an earthen **nand** over which has been placed a rectangular structure of wicker-work or of bamboo in order to allow the molasses to trickle down into the receptacle below. If earthen pots have been used for storing the **rab** as is the rule in Rohelkhand and other places, the pots have to be broken before the massecuite can be taken out. This process is open to the serious objection that small particles of earthen pots when broken get mixed with the **rab** and ultimately contaminate the sugar from which they cannot be separated by the sieve or any other contrivance. That is one of the reasons why the indigenous **khand** has to be dissolved and the solution strained and boiled to make the table sugar **bura.** It is desirable, therefore, that the vessels meant for storage of **rab** should be made either of wood or of galvanised iron. Kerosene tins may certainly be used in preference to earthen vessels though their present cost (6 annas per tin) is rather high and they are not sufficiently durable but they are more economical than **kalsis** in the long run. The **rab** should be scraped with the iron scraper known as **khurpi** and collected in an iron receptacle. If the business is a small one, as would be the case when a single hand or bullock-driven centrifugal is employed, it would not be worth while purchasing a pug-mill for use, but the latter would be essential for working a power centrifugal. For using with a small centrifugal the lumps in the **rab** should be broken by hand with a wooden peg, the wedge end of which should be kept upwards to prepare a homogeneous mass which is then placed on the rough filter described above for one or two hours, preferably in the sun, except when, towards the end of the cold season, the sun is so hot that it dries the **rab** to an undesirable degree. The separation of some of the molasses in this way renders the **rab** much easier for working through the centrifugal. Exposure of **rab** to the sun is however by no means essential and the **rab** may, as soon as the lumps have been broken, be considered ready for

Belt-Driven Centrifugal

With Central Bottom Discharge.



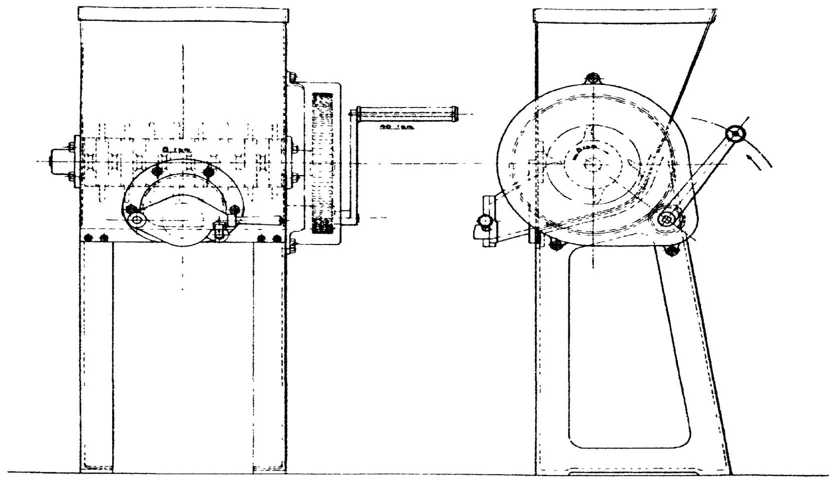
Type No. 17A.

Made by

THOMAS BROADBENT & SONS, LTD.,

HUDDERSFIELD.

Diagram of Hand-driven Pugmill



MADE BY THOMAS BROADBENT & SONS, LIMITED, HUDDERSFIELD, ENGLAND

machining. When preparing the material for a power-driven centrifugal machine, the **rab,** after removal from the pots, should be transferred at once to the pug-mill to break the lumps. When digging the **rab** out of a kerosene tin with the iron **khurpi,** care should be taken to use the instrument with caution, so as not to pierce the walls or the bottom of the vessel which would make it unfit for further use. A successful method of taking the hard massecuite out of the tin is to dig a thickness of about one inch of the crystallised mass on each side of the tin down to the bottom, and then give the vessel one or more shakings so that the rest of the contents may come out in the shape of a big lump or lumps. Inexperienced labourers would ordinarily try to scrape the **rab** out in small quantities and thus shorten the size of the crystals to such an extent that they might escape through the mesh of the centrifugal in the curing process resulting in a lower yield of sugar. The same precaution should be taken when the **rab** has to be taken out of crystallisers larger than the kerosene tins.

Sufficient molasses from previous collections mixed with a solution of Sodium hydrosulphite (about half a tea-spoonful of the chemical to every standard maund of **rab**) should be poured into the pugmill to reduce the consistency of the mass to the proper degree. In the absence of a pug-mill, the molasses treated similarly with Sodium hydrosulphite should be added to the mass and thoroughly mixed with it by hand. If the **rab** to be treated in the centrifugal is viscous, which is often the result of careless boiling. the removal of the molasses is made easier if one or two drams of bicarbonate of soda are dissolved in a weak solution of Sodium hydrosulphite and stirred into the molasses till it becomes frothy before it is added to the **rab.** When the **rab** is abnormally sticky a larger quantity of molasses treated liberally with the bicarbonate should be poured on to the charge in the centrifugal from a galvanised iron **balti** while the machine is running at full speed. With superior specimens of **rab,** it would be well to avoid the soda treatment altogether, as there is a fear that the treatment, though it helps materially in speedy elimination of the syrup, might adversely affect crystallisation of the second **rab.** The charge, without the molasses added, should weigh about 50 lbs. Care should be taken to see that all bearings are properly oiled and then the machine may be started, slowly at first. When full speed has been attained, it should, as far as possible, be maintained until the purging is complete.

It will be found that the cage in Weston type centrifugals, if charged when the machine is at rest is liable to violent shaking ("pounding") under the influence of unequal distribution of the basket load, when it is set in motion. This is very often the case when the **rab** charged is full of unbroken hard lumps or unusually

viscous so that the spindle and basket cannot balance themselves. Should such a circumstance arise, the only way to give the running machine a chance of balancing itself is to hold the spindle between two pieces of bamboo placed crosswise on the lid covering the basket, and allowing the cage to revolve very slowly until part of the molasses has been thrown out when it will begin to run steadily. The bamboos should then be removed and the normal speed gradually attained. This treatment would however be ineffective if the **rab** was full of hard lumps of different sizes, rendering equal distribution of the mass in the cage impossible. In the latter case the machine must be stopped, the contents of the cage taken out, the lumps broken properly and the **rab** with a fresh addition of molasses charged again. When a charge of undue viscosity is being treated in the centrifugal and the shaking of the basket is not immoderate, the irregularity in the motion may be checked by pouring into the cage, while it is running, about 8 or 10 lbs. of molasses diluted with about 20% of its weight of water, to help quick elimination of the thicker molasses contained in the charge. Under-driven centrifugals such as the "Handelox" are not liable to this drawback and as a rule run steadily when charged at rest. For all Weston Type machines it is much safer to prepare the **rab** more thoroughly by crushing the lumps with the hand or in a pug-mill and then charge them when running at fairly high speed and this is the course recommended on the basis of experience gained on working several of them. Towards the end of the curing operation, the contents of the cage should be washed with a syringe, using a very weak solution of Stannous Chloride in warm water to remove the film of molasses from the surface of the sugar crystals, and to allow the last traces of molasses to pass through the mesh. The makers usually supply a brass syringe with the centrifugal. Ordinarily, about two syringefuls of the solution suffice for each charge to obtain a high grade **Khand** from good **rab,** but if the **rab** has been badly prepared, or the full speed has not been maintained throughout the spinning, an extra syringe of water may be found necessary, though this is seldom the case. It must be borne in mind that every spray of water distributed over the revolving mass means a certain loss of first (white) sugar, though the loss is balanced by a corresponding increase in the recoverable percentage of the second (a some what lower grade) sugar spraying should therefore, be done with great caution and rather sparingly. Although high grade specimens of **khand,** centrifugally cured, receive due appreciation in the Indian market, the real need of the Indian confectioner does not lie mainly in sugar of absolute whiteness or marked brilliancy. A sugar of average whiteness which would behave well in his pan, i.e., which possesses a fair strength of crystals, is all that is needed at present. He is in no way particular regarding the size of crystals. Indeed small grains receive more favour than the larger ones and the crystals have

therefore to be made smaller by mechanical means after the sugar has been taken out of the cage. The manufacturer would therefore be well advised to gauge his market as to the colour and quality in demand, and wash his first sugar only to the limit desired from the economical standpoint.

A sample with a polarisation of about 96° would sell in the Indian market quite easily and at present dearer than foreign sugars. Specimens of higher purity would bring a little better price but not commensurate with the loss due to washing in order to obtain them. However, as loss is mostly recovered in the shape of the second sugar afterwards, the manufacturer should and can adjust his processes so as to obtain the highest monetary return in his business. If stannous chloride is not available a weak solution of hydrosulphite of sodium should be used for the last washing, as it improves the colouring of the sugar quite distinctly and the resulting molasses yields second sugar which is fairly white, a distinct economic advantage.

Rab prepared from some of the canes specially Yuba (S39) and **Nasik Khadia** generally yields first sugar of small crystals having a very slight pale tinge of colour which, though not objected to by the common confectioner, slightly reduces the market value. This is not the case with any of the local red or Java canes or the Coimbatore seedlings which always give beautiful white sugar, the only exception being Co. 213 and Co. 214 which yield sugar of very strong medium-sized crystals but inferior colour. The said tinge of colour becomes lighter by exposure of the sugar to the bleaching action of the sun and it can also to a certain extent be disguised by giving the second washing with a solution of ultramarine, blue, the strength of which can be regulated according to the market requirements. The machine should be stopped when purging is complete, this being a matter of judgment from the appearance of the charge and the gradual cessation of the molasses drip.

The sugar should now be scraped from the walls with the wooden **khurpi** and lifted by hand into a tray, unless the machine used is fitted wih a bottom discharge. In the latter condition the sugar should be emptied into a wooden oblong receptacle placed below the machine.

The product thus obtained occupies the same place as **Pachhini"** (scrapings of the sewar treated layer of the **rab**) in the **khanchi** system but it is usually very much whiter and cleaner than the **"phul,"** in the finest form of the Rohelkhand **khand,** and incomparably superior in colour to the indigenous low grade sugar

known as **"adhauta"** and **"taruncha."** While it is essential for the **pachhni** to be spread on a **tat** matting (**pata**) in the sun to be crushed by labourers with the feet for bleaching purposes, it is entirely unnecessary in the case of the centrifugal product to resort to that process so objectionable from the standpoint of hygiene and cleanliness, and this is one of the achievements of the new process.

Although the sugar obtained from the centrifugal is saleable without any further treatment (provided the **rab** was potted in tins instead of earthen jars and the sugar is free from broken particles of the clay vessels), being good enough for the ordinary requirements of the Indian confectioner, it would be well in order to give the sugar a better finish to roll it over while it is still slightly moist on a plank of wood placed on the **pata** in the sun with the common kitchen roller known as **belan.** This process improves the colour of the dried sugar most remarkably, any lumps contained in the exposed sugar mass being crushed and the size of the crystals reduced at will to the limit fancied most by the consumers. Uncured or only partially cured lumps can be conveniently separated during the rolling operation and placed aside to be refined or they may be crushed in the local **chakki** (grinding mill) into powdered white sugar which always finds a ready sale. The sugar when thoroughly dried in the course of 6 or 7 hours should be passed through sieves of varying degrees of fineness in order to produce the desired grade or grades, the larger crystals being further subjected to the rolling process to make them finer and then passed through the proper sieve. The sugar should then be put into bags kept overnight and dried again the next day until no traces of moisture are perceptible and then bagged finally for the market.

In case of a large power-driven centrifugal, the basket is fed by opening the orifice in the pugmill and allowing the mixture of crystals and molasses to run into the cage to the extent of the capacity thereof. In steam-driven sets there is often an arrangement for letting steam from the boiler into the cage while it is spinning. This might be done towards completion of the curing to remove the molasses still adhering to the crystals, but here again care should be taken to use only as much of the steam as would satisfactorily secure the object and no more. If undue loss occurs, the process should not be used, but with abnormally viscous or hard **rab** the method will be found very beneficial. The steam acts in two ways. The elevated temperature makes the molasses separate more easily from the crystals and the water resulting by condensation of the steam provides washing liquor and so improves the colour of the final product. If superheated dry steam could be introduced, it would not dissolve sugar, and neither would hot

air, but to obtain a high grade **khand** the solution of a certain amount of sugar is inevitable. With good **rab,** it would probably be best not to use steam but wash with warm water. A syringe may be used for this purpose but a better plan will be to have a nozzle arrangement fixed to the centrifugal whereby warm water could, when desired, be evenly spread over the revolving mass by merely turning a tap and lowering or raising the nozzle. The molasses, with the exception of the quantity required for mixing with the **rab** for the day's work, should go to the boiling shed and be converted into second **gur** or second **rab without delay.**

After taking out each lot of sugar, the basket should be syringed with water or wiped with a wet piece of rag.

In the power centrifugal, there is generally an arrangement for cleaning the mesh by a steam jet which should be used to prevent the perforations from being choked with the finer particles of sugar. The receptacles used for the storage of **rab** should be well washed with water in order to dissolve the sugar sticking to them and if they were earthen pots, which are porous as a rule the broken pieces should be placed in a pan of boiling water and kept there until the sugar has been extracted; the solution should then be strained through a fine piece of cloth and added to the molasses for reboiling.

The second **rab** is never so hard as the first. It should be stored for crystallisation in kerosene tins in preference to the earthen jars and should be allowed a period of about three weeks' rest. On account of its soft texture it can be taken out of the tins with comparative ease to be cured in the centrifugal. If the first molasses from which the **rab** was made had not been boiled while quite fresh, and with due rapidity, or if the cane juice was originally wanting in richness, or if a very high extraction of first white sugar had been obtained from the first massecuite, the second **rab** resulting from the first molasses will be found to be covered with a spongy layer of varying thickness on the surface of the tins. This is technically known as **"gobh"** and consists of minute sugar crystals imbedded in a sticky mass, unsuitable for machining on account of its gummy character. This layer should with advantage be removed to be subsequently converted into molasses or a low grade **gur.** Beneath this layer and down to the bottom will be found crystals mixed with molasses. Second **rab** prepared from rich molasses is usually free from the **"gobh."**

In order to prepare the second **rab** for a centrifugal charge, it is essential to mix it with molasses treated with sodium bicarbonate as described before and with sodium hydrosulphite, before it is put into the basket. If the machine used is one of 18″ diameter a charge of 50 lbs. of **rab** will be quite suitable. The smaller centrifugal of 14″ diameter will however deal with only about

40 lbs. at a time properly. As soon as the charge has been put in, about 8 or 10 lbs. of molasses from a previous operation should be taken in a basin, diluted with about one-fourth of its weight of water into which a dram of sodium carbonate and about 5 grains of sodium hydrosulphite have been dissolved to bring the molasses down to the consistency of a syrup (about 59° Brix). When about half of the molasses has been separated from the **rab** revolving in the centrifugal, the contents of the basin should be poured into the basket all at once. This will help quick elimination of the remaining adherent molasses from the sugar mass, and the resulting sugar will be fairly white (about 96° pol.). If this treatment is not adopted, the sugar will be pale. In subsequent charges the soda treatment of the molasses to be added to the **rab** will not be necessary as the effect of the soda once mixed with the molasses will be found to last for some time. But the use of the hydrosulphite with each charge is essential for obtaining a good quality. Washing the sugar with a weak solution of stannous chloride is equally necessary, because it specially improves the colour of the sugar and more so than a solution of sodium hydrosulphite or ultramarine blue. The treatment to be adopted after the second sugar has been discharged from the centrifugal is the same as that of the Ist. sugar.

The action of the hydrosulphite in improving the colour and quality of the second sugar and reducing the viscosity of the second **rab** is much more marked than when the same agent is used with the first **rab.** The reason has not yet been understood. But it is a fact that while second sugars of the desired degree of whiteness are never obtained without the admixture of the hydrosulphite, the latter does not show any appreciable difference in the colour and quality of the first sugars made with and without its use. On the other hand the addition of the hydrosulphite to the first **rab** sometimes imparts a pale tinge to the resulting first sugar, while the same **rab** machined without mixing the chemical produces a slightly whiter specimen. So far as its use with the first **rab** is concerned the question is therefore one for further investigation. Presumably the yellow colouring matter originally present in predominance in the cane, e.g. in Co. 213 and S. 39, and in the **rab** made therefrom, becomes so intensified or otherwise affected by the addition of the hydrosulphite as to impart a tinge of its own to the crystals. In dealing with his first **rab** the manufacturer can only be advised at this stage to test the effect of it with a specimen of the lot of **rab** he has to cure and to dispense with the use of the chemical if it affects the colour of the sugar adversely.

Finally, as the author's experience is confined to Broadbent's machines, he has in this chapter mentioned those of their various types that have so far been tested in India from the commercial

standpoint, but it is not suggested that centrifugal machines made by other manufacturers after studying the requirements of Indian **rab** would not give satisfactory results.

The following table indicates the working capacity of the various types of Messrs Thomas Broadbent & Sons hand-power centrifugal tried exhaustively at Bhopal with specimens of first **rab** made from superior cane varieties under the new system, the average working period being a day of 8 hours:*—

Serial No.	Type of machine.	Average weight of **rab** charged in the basket at a time.	No. of labourers employed	Average weight of **rab.** cured per hour in actual working.	Speed at which the machine was designed to run.	Average weight of **rab** worked during the day
1	Weston type 18″ Diameter gear-driven hand-power centrifugal type 16A	56 lbs.	8	155 lbs.	1800 revolutions per minute.	1240 lbs. or 15 standard maunds.
2	Weston type belt-driven 18″ diameter type 16, the "Hestogal."	56 lbs.	8	140 lbs.	1800 revolutions per minute.	1120 lbs. or 13.5 standard maunds.
3	Weston type 14″ diameter gear-driven hand-power type 16A	40 lbs.	6	120 lbs.	Do	960 lbs. or 11.6 standard maunds.
4	Under-driven 18″ diameter type 12, the "Handelox"	56 lbs.	8	105 lbs.	1700 revolutions per minute.	840 lbs. or 10 standard maunds.

*In the United Provinces the working day in small sugar factories ordinarily varies from 10 to 12 hours and the output in that part of India will be larger proportionately.

The first three of the above machines are all designed to run at 1800 revolutions per minute and will run at that speed if the labourers could work hard continually, but in actual practice, the average speed maintained cannot be regarded as exceeding 1500 revolutions unless the machine is worked by an engine. The Malwa labourer is not yet accustomed to hard work, or else about 18 maunds of **rab** could be worked into sugar of very good quality during the day. In Shahjahanpur as much as 25 maunds of **rab** is dealt with on a system of contract with the labourers, but there, the quality of the sugar is inferior partly on account of defects in the boiling of **rab,** and partly owing to imperfect elimination of molasses, as a result of the hurry with which the work is done usually in all contract systems.

All types of 18″ diameter are capable of holding a maximum charge of 67 lbs. of first **rab** of good quality but it is not advisable to work them generally with such high loads. The finest quality of sugar is made from the "Handelox" which is designed to run at about 1700 revolutions per minute, though the daily output obtained is the least in comparison with other types worked by labourers. When driven by power the "Handelox" works up quite 15 maunds of first massecuite during the day. If the "Handelox" is designed to run at 1800 revolutions per minute a great improvement in the quality of the sugar and the output will probably be the result. Intending purchasers will be well advised to specify the above speed when ordering that type. If power is available and it is intended to work with 18″ diameter centrifugals, it is recommended that the "Handelox" should be used in preference to any other small type supplied with a power-driving arrangement. The only disadvantage of the "Handelox" is that it has not got the bottom-discharge facility, which necessitates removal of each discharge by the hand, but that is counterbalanced by the fine quality of the first and second sugars it usually turns out and the ease and efficiency with which it deals with the inferior and more or less viscous second massecuites, without upsetting its balance. For working with hand power, however, the latest type Serial no. 1 on the above table, would be found most economical. Serial No. 3 is an admirable machine specially suited for working the second **rab,** because of the less power it demands and the ease with which the speed can be maintained throughout the spinning process. Although it can be worked by a team of 4 labourers, it is better to employ 6 men. It makes as good first sugar as the other Weston type machines and will therefore be very useful to those who would like to start a sugar business on the minimum Cottage Industry scale. Serial no. 2 is more steady and has the advantage of running noiselessly which is not the case with Serial nos. 1 and 3. Serial no. 2 worked perfectly satisfactorily during the second Research Season but in the third season for some reasons, which could

not be ascertained, it imposed extra hard work on the labourers Presumably the rubber buffer needed renewal. It would therefore be unfair to declare at this stage that it is inferior to other Weston type machines until the defect has been detected and removed and the machine tried again. It can safely be said that any of the 1st three machines enumerated in the above table would answer well for working on a commercial basis on the Cottage Industry scale with hand-power, as they are all capable of extracting high percentages of sugar of superior quality. For working with an engine the "Handelox" would be found preferable.

For a hand-power 18″ centrifugal in a village, the daily cost of working would be:—

	Rs.	as.	p.
Wages of mechanic to look after the centrifugal and exercise general supervision over the machining operations	0	10	0
Wages of 8 labourers to drive the machine at 8 annas each	4	0	0
„ 2 women to crush and dry the sugar at 3 annas each	0	6	0
„ 3 labourers for breaking the **rab** and doing miscellaneous work at 4 annas each	0	12	0
Oil	0	2	0
Chemicals (Soda etc)	0	2	0
Depreciation @ 10% of the cost of the whole plant (Rs. 1400) and interest @ 6% on the same, assuming that the centrifugal will work 6 months in the year	1	4	0
Total ..	7	4	0

With 8 labourers, the best 18″ diameter machine can be worked quite conveniently in Malwa for 8 hours a day, during which it should deal with 15 standard maunds of first **rab** which is a fair daily average. Thus the actual cost calculates to 7.73 annas per standard maund or 9.27 annas per Bhopal maund of **rab,** or roughly about Rupee 1/- per standard maund of first sugar produced (47 p.c. of **rab**).

Dealing with the second **rab** made under the new system, 10 standard maunds is about the limit which can conveniently be worked into second sugar in 8 hours, the usual working period in a hand-power installation. That quantity should yield at least 3 standard maunds of second sugar on an average. The working cost would thus calculate to 11½ annas per standard maund of second massecuite cured or Rs. 2-7-0 per standard maund of second sugar obtained.

Broadbent's machine type no. 20, which appears to be well suited for Indian conditions where steam is available, has not yet been tested by the author but on the basis of the past experience with an older machine similar in several respects to the above and tried in Rohelkhand and at other manufacturing centres, with **rab** boiled under the Rohelkhand **bel** system working 12 hours a day (as is usual), it may safely be assumed that the cost would be about three annas per standard maund of first **rab** treated, or 9 annas per standard maund of 1st sugar produced, (nearly 35% of the weight of the **bel**-made **rab.** In Bareilly where Broadbents, power-driven 30″ diameter machines are in use about 62.5 standard maunds of second **rab** is worked into second sugar in 12 hours, the yield of the latter being 20% of the **rab** in weight or 12½ standard maunds. The cost of machining calculates to about 4 annas per standard maund of second **rab** or Re. 1-4-0 per maund of second sugar.

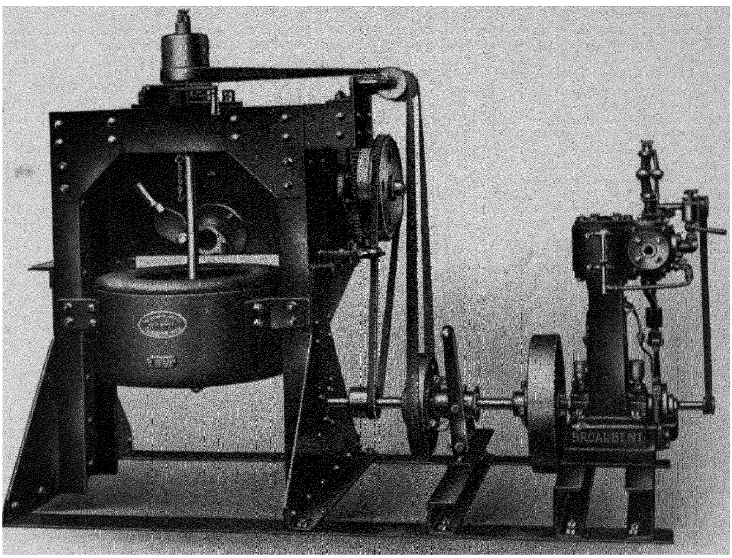
It has, however, been proved by repeated trials that the use of the hand-power easy-running centrifugals is perfectly practicable from an economic and commercial point of view as a measure suitable for adoption in the cottage industry.

Since this book went to the press a new type of Messrs Thos: Broadbent & Sons' 18″ power Centrifugal combined with an oil Engine was tried at Bhopal. The results will be found in appendix A.

18-in. Suspended Centrifuge

(Over-driven Type)

Combined with Vertical Steam Engine and Pugmill.

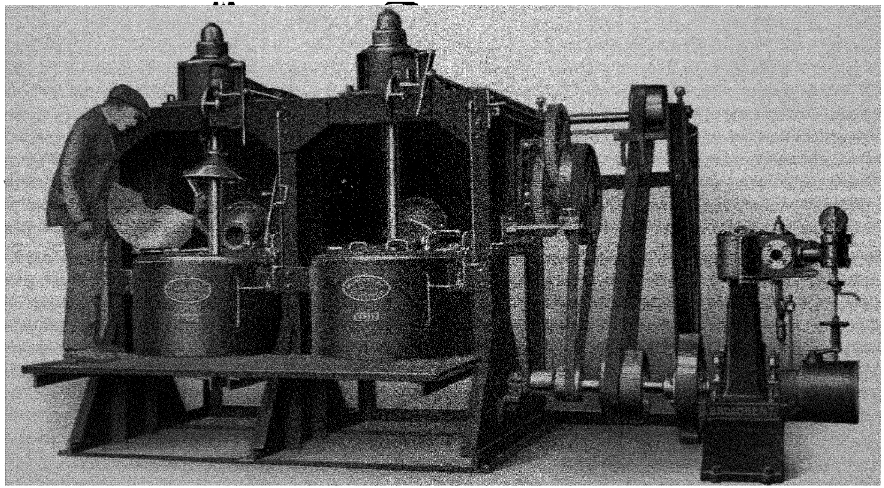


A COMPLETE SELF-CONTAINED UNIT.

MADE BY
THOMAS BROADBENT & SONS, LIMITED,
HUDDERSFIELD, ENGLAND.

Battery of Two 30-in. Over-driven Centrifuges

Combined with Pugmill to serve both Machines, 12-H.P. Vertical Steam Engine, and 40-H.P. Cornish Boiler (not shown in illustration).



By means of Control Levers, either one machine or both machines can be worked at the same time, or the Pugmill can be worked when the machines are standing.

CHAPTER XV.

The present condition of the trade in Sugar made by the Centrifugal Machine in Upper India.

Notwithstanding the discouraging pronouncements made from time to time against the possibilities of economic success of the Indian methods of making white sugar direct from the cane with the help of the centrifugal machine, the fact remains that the machine has had a most welcome reception in the native factories during the past two decades, and slowly but not imperceptibly displacing the old **khanchi** system in Rohelkhand where the number of centrifugals now in use is considerable, and every year witnesses further additions to it. This is a clear evidence of popular recognition of the usefulness of the machine as an appliance leading to an increased yield of the sugar and a quick return of the money invested in the sugar business. Indeed it seems that before long the **khanchi** will be an object of antiquarian interest in Rohelkhand.

The hand power 18″ centrifugal of the Weston type is most largely in use in the District of Shahjahanpur (U.P.) where the manufacturer who is generally the owner of the machine, works the Indian **bel rab** with it through a gang of 9 labourers, on a contract system, paying them at the rate of one anna for every 20 standard seers of **rab** cured. In addition each labourer gets as much molasses for taking a cool drink (**sharbat**) as he may want besides, quarter of a seer of parched gram for his midday meal. The work usually starts at 8 A.M. and lasts till 8 P.M. with a recess of about an hour at noon. The quantity of **rab** dealt with during the day varies from 25 to 27 standard maunds, the yield of sugar being about 40 per cent of the weight of the **rab,** roughly between 10 and 11 standard maunds. The mass of sugar when revolving with the cage is as a rule washed with a decoction of dried Ritha fruit (Sapindus Mukorossi) together with some alum and sodium bicarbonate in solution. The use of the **ritha** as a detergent was first introduced by the author, but has been found open to objection because of the astringent taste it might impart to the molasses, if used in excess. Alum is known to the Halwais as an agent which weakens sugar crystals in boiling and soda exercises a similar action though in a smaller degree. The use of all these agents must therefore be deprecated. Indeed, if the **rab** is superior, the need for the use of detergents should entirely disappear. It is here that the **khandsari** has been making the greatest mistake so far. He should prepare better massecuite instead of trying to find means of obtaining impossible results from his inferior article.

About one seer of the **ritha** decoction is used for washing with the syringe in two instalments from 30 to 35 seers of **rab** which usually forms a charge for the machine, the first washing being done about 5 minutes after the start and the second a couple of minutes later.

A few years ago, the Shahjahanpur manufacturers invariably employed aniline blue or ultramarine for washing their sugar in the machine. It was, however, found that the disguise in the yellowish colour of the crystals was only a means of pleasing the purchaser's eye temporarily; the blue colour made its appearance in the pan when this sugar was boiled, a feature which received the universal disapproval of the confectioners and the use of the substance was consequently abandoned.

There can be no clearer evidence of the highly defective quality of the **rab** ordinarily made in the Rohelkhand **bel** than the circumstance that in every charge put into the hand centrifugal, the innermost layer of the sugar in the machine, varying from 1 to 4 seers in weight, usually remains uncured in spite of the fact, that so far as high speed is concerned, the factory is provided with the best hand centrifugal India has hitherto received. The outer layer of the finished product has therefore to be carefully scraped in and let out. The outlet has then to be closed and the uncured layer has to be scraped in to be cured with the next charge. This process is continued throughout the day.

The repulsive system of crushing the cured sugar under the feet on the pata in the tropical sun which exercises a marked bleaching action on the **pata** crystals is still indispensable and must continue to be so until the method of boiling the massecuite is materially changed for the better.

At its best, the sugar so prepared is a more or less pale article, the fine crystals composing it being thinly covered with traces of molasses, and it has a flavour disagreeable to most tastes which persists until the sugar has been re-boiled. It is not fit for table use unless refined into **bura.**

The cost of manufacturing **khand** by a hand power centrifugal dealing on the average with 26 standard maunds daily from **rab** in Shahjahanpur is calculated below :—

	Rs.	a.	p.
9 men on contract for curing the **rab**	3	4	0
3 men for the **pata**	0	10	6
Perquisites given to labourers :—			
Sharbat 0-3-0 .. .. } Parched Gram 3 seers 0-8-0) }	0	11	0
Depreciation on machine (cost Rs. 925)	0	10	6

	Rs.	a.	p.
House rent	0	8	0
Supervision charges	1	0	0
Lubrication	0	1	0
Soda	0	0	6
Alum	0	0	6
Ritha	0	1	0
Firewood to boil the decoction	0	1	0
Total ..	7	0	0

Cost per standard maund of **rab** machined. $\frac{112.0 \text{ annas}}{26 \text{ maunds}}$ = 4.3 annas.

Cost per standard maund of first sugar obtained. $\frac{112.0 \text{ annas}}{10.4}$ = 10.8 annas

In Bareilly the more enterprising business-man generally uses a power centrifugal of 30 inches diameter combined with a 3 B.H.P. steam engine and boiler costing Rs. 7,000/. His daily working expenses are as follows :—

	Rs.	a.	p.
7½ Standard maunds of coal	4	0	0
8 Chhataks of castor oil for lubrication	0	4	0
1 lb. grease	0	5	0
Packings, etc.	0	4	0
One driver @ Rs. 40 p.m.	1	5	3
One fireman @ Rs. 20 p.m.	0	10	9
Depreciation at 10% per annum on the cost of the plant assuming the working period to be 6 months about	4	0	0
25 labourers at Rs. 10/- p.m. (21 for drying and crushing the sugar on the **pata** and for breaking the **rab** pots and preparing the **rab** for the machine, 3 to attend to the machine and one extra labourer to relieve the above occasionally	8	5	3
3 female labourers for scraping **rab** from the broken pieces of pots @ annas 3 each	0	9	0
One **Behishti** (water-carrier)	0	4	6
	19	15	9
Add house rent	4	0	0
Total ..	23	15	9

The quantity of **rab** treated during the working day of 12 hours is on the average 63 Bareilly mds. equivalent to 78.75 standard mds. yielding 22 Bareilly mds. or 27.5 standard mds. (a little over, one ton) of 1st sugar (or 35 per cent of the **rab**) besides

51.25 standard maunds of 1st molasses. The cost of manufacture of 1st sugar from the **rab** thus amounts to :—

$$\frac{383.75 \text{ annas}}{78.75 \text{ Std. Mds}} = 4.8 \text{ annas per standard maund of } \textbf{rab} \text{ treated}$$

and $\frac{383.75}{27.5} = 13.9$ annas per standard maund of sugar produced. It will be seen that the cost of production here is higher than at Shahjahanpur and the yield of sugar less in quantity by about 5 per cent, but being superior in quality it sells dearer in the market and is less subject to the objections to which the Shahjahanpur sugar is liable. In storage too, it does not deteriorate to the same extent as the inferior Shahjahanpur product.

Unlike Shahjahanpur where the **shira** molasses is usually poorer in sucrose due to higher yield of first sugar and is generally sold as such, the manufacture in Bareilly converts the first molasses either into **rab** or **gur** by reboiling the material while fresh, the cost of boiling 51.25 standard maunds of the molasses into **rab** being as under :—

	Rs.	as.	p.
5 Standard Maunds of firewood	3	0	0
Wages of one expert boiler	1	4	0
5 labourers for firing the furnace and airing the **rab** at Rs. 10/- p.m. each	1	10	8
8 chhataks of castor seed	0	2	0
Sajji (black)	0	2	0
	6	2	8
Add, house rent, ...	2	10	8
Total ..	8	13	4

The weight of the second massecuite obtained from 51.25 standard maunds of first molasses amounts to 42.5 standard maunds or nearly 83 per cent of its weight, the cost of the second boiling being :—

$$\frac{141.33 \text{ annas}}{51.25 \text{ mds.}} = 2.75 \text{ p} \quad \text{standard maund of molasses boiled or}$$

$$\frac{141.33}{42.5} = 3.3 \text{ annas per standard maund of second } \textbf{rab} \text{ produced.}$$

The second **rab** is sometimes stored in earthen jars but generally in masonry pits of about 400 cubic feet capacity in which it is left to crystallise slowly for 4 to 5 months, and is usually treated in the centrifugal when the manufacture of first sugar made for the season has been finished. Then it yields nearly 20% of its weight of second sugar (yellow).

The above quantity of second **rab** (42.5 Std. Mds.) is machined in the power centrifugal in 8 hours at a calculated cost of Rs. 9-14-4 or $\frac{158.33 \text{ annas}}{42.5 \text{ Mds.}} = 3.7$ annas per standard maund of **rab** treated and yields a little over 8 standard maunds of second sugar, the cost of production per maund of this sugar being $\frac{158.33 \text{ annas}}{8.12}$ 19.4 =Rs. 1-3-4 per maund of second sugar.

With these data may be determined easily, as follows, the daily profits of the proprietor of a power-driven centrifugal who owns no **bel** and carries on the sugar-making business in its least remunerative form, i.e., by purchasing **rab** from the producer under the **Khush-Kharid** system at a price substantially higher than the cost price :—

Expenditure.	Rs.	as.	p.
Cost of 63 Bareilly Mds. of **rab** @ Rs. 8/- per Bareilly Md. (1.25 Std. Md.)	504	0	0
Cost of centrifugalling the above to make first sugar as per detail given above	19	15	9
Do. boiling the first molasses	6	2	8
Machining molasses **rab**	9	14	4
House rent Rs. 4/- plus Rs. 2-10-8 (see details above) ..	6	10	8
Cost of supervision (actual)	7	0	0
	553	11	5
Manufacturer's profit for the day (nearly 8% on the day's investment)	44	0	7
Total ..	597	12	0

Income	Rs.	as.	p.
Price of 22 Bareilly Mds.=27.5 Std. Mds. of 1st sugar at Rs. 20/- per Bareilly Maund (50 Std. Seers) ..	440	0	0
Price of 6½ Bareilly Mds. =8-12 Std. Mds. of 2nd Sugar @ Rs. 13-8-0 per Bareilly Maund	87	12	0
Price of 28 Bareilly Mds=35 Std. Mds. of second molasses @ Rs. 2-8-0 per Bareilly Md.	70	0	0
Total	597	12	0

Owing to the weakness of the Rohelkhand **rab** as it is generally made at present with the indigenous **bel,** the manufacturer finds it more remunerative to convert the first molasses (which contains only about 20% of recoverable pale sugar) into second **gur** instead of boiling it into second massecuite. The cost of centrifugalling is thus saved and the strain caused on the machine due to the viscosity of the second **rab** is also avoided. Further there is a small saving of labour on the boiling, only 3 workmen being required instead of 5 employed in the boiling of **rab.**

The yield of second **gur** from 41 Bareilly Mds. (51.25 Std. Mds.) of the first molasses collected during the day amounts to 31 Bareilly maunds = 38.75 Std. Mds. or 75.5 per cent of the molasses compared with 83 per cent of second **rab** obtainable from the same quantity. There is no sale for the second **rab** in the Rohelkhand market and it is unsuitable for export though it could sell readily in the tracts of country where cane cultivation is limited, such as in Central India, if it could be put on the market.

The second **gur,** however, finds a demand for it in parts of the Punjab and in the Hindu States of Rajputana where cane is scarce and all saccharine products are looked upon as dainties. Nearly the whole of the second **gur** produced in Rohelkhand is now exported to the tracts where the article is welcomed. It should be mentioned that before the inception of the centrifugal machine little second **gur** was made in Rohelkhand because it was found impossible in practice owing to the fermentation which set in before the molasses were available in quantities sufficient for boiling on a commercial scale. If any quantity was boiled, the product failed to solidify. By enabling the owner of the centrifugal to overcome this disadvantage, the machine has opened out a new line of trade to the manufacturer.

The cost of boiling the above quantity (41 Bareilly maunds = 51.25 Standard Maunds) of molasses into second **gur** comes to Rs. 8/10/- i.e. $\frac{138 \text{ annas}}{51.25 \text{ Std. Mds.}} = 2.7$ annas per Std. Md. of molasses or $\frac{138 \text{ annas}}{38.75 \text{ Std. Mds.}} = 3.5$ annas per Std. Md. of second **gur** produced.

It is calculated that the increase in the income to the manufacturer who boils molasses into **gur** instead of extracting second sugar from it amounts to about Re. 1/- per Bareilly Maund of molasses. The reason why second sugar is then made lies in the fact that the sugar has better keeping qualities, while the second **gur,** if not sold quickly, would very seriously deteriorate in storage on account of its great hygroscopic property.

Because a power-plant for crushing the cane and machining the **rab** has not yet been fully tested in Bhopal, the author is unable to furnish any figures to his readers for such an enterprise on the basis of local experience.* But in order to enlighten such of them as would like to form an idea of the possibilities in case it is intended to work on a larger than the cottage industry scale, it would be well for them to glance over the actual figures (which are available in detail) of a small power factory working in a district bordering Rohelkhand.

The initial outlay of this moderate concern is :—

	Rs.	as.	p.
Buildings	13,000	0	0
One 16½ B.H.P. Crude oil engine	3,600	0	0
3 power-crushers, each having rollers 8″×8″, manufactured by Messrs Massey & Co. of Madras.	2,700	0	0
2 Weston type 18″ centrifugals made by Messrs Thomas Broadbent & Sons	2,200	0	0
Boiling pans, shafting, fittings, etc	2,500	0	0
Total	24,000	0	0

The cane is purchased from the cultivators under a system of **takavi** advances at 7 to 7½ annas per standard maund (delivered at the factory) of indigenous varieties and at 8½ annas per standard maund of S.48 which is grown in the neighbourhood. It is crushed with the three power crushers and the juice obtained is boiled in a set of two Rohelkhand **bels** of average dimensions, working 10 hours a day. The **rab** is stored in kerosene tins instead of earthen jars and machined to obtain first sugar. The molasses is re-boiled for extraction of second sugar.

When the factory was visited for the purpose of obtaining this information, one of the crushers was out of order and only two were working, which crushed 450 Std. maunds of cane during the day, extracting 270 to 280 Std. maunds of juice, or 60 to 62 per cent of juice on the cane. The juice on boiling produced 18 to 20 per cent of its weight as **rab,** the daily output of which varied from 50 to 55 standard maunds, bagasse alone being used as fuel, except on cloudy days when not dry enough. The use of kerosene tins instead of earthen **gharas** for potting was attended with obvious advantages, the sugar produced being much cleaner and free from the broken particles of the baked jars, also the labour of washing the broken pieces of the earthen vessels not being required, brought about a distinct saving. This practice has been found to be very economic, too, in the long run and it is highly desirable that it should be universally adopted by all manufacturers of Indian

* The reader is invited to refer to appendix A. for results of trials of a power crusher since the above was written.

sugar in view of the marked improvement which results in the quality of the outturn. Below is given a detail of the daily expenses incurred in the factory :—

	Rs. as. p.	Rs. as. p.
Working the Engine.		
2 bottles of kerosene oil	0 5 0	
6 gallons of crude oil	3 12 0	
1½ lbs. of Cylinder oil	0 5 3	
2 Chhattaks of cotton waste	0 1 3	
Pay of the driver	2 0 0	
Lubricating oil	0 5 0	
Miscellaneous	0 3 6	
	7 0 0	7 0 0
Working the two crushers		
6 labourers to feed the mills	1 14 0	
2 boys to remove the bagasse ..	0 6 0	
2 females to carry the above to the drying yard	0 6 0	
Lubrication	0 2 0	
	2 12 0	2 12 0
Note. 450 Mds. of cane was crushed at a cost of Rs. 9-12-0, the incidence being about 4 pies per Md. of cane crushed or 7 pies per Md. of juice obtained, exclusive of depreciation on machinery and buildings (allowed later in this account)		
Boiling the rab. This work was done in the usual manner according to the practice prevailing in Rohelkhand (details to be found in chapter XI) by two **bels** at a cost of Rs. 9-13-9 (incidence, 3 annas. per Md. of **rab** or 6.9 pies per md, of juice)	9.13 9	9 13 9
Working the two centrifugals to cure 50 to 55 mds. of rab in 12 hours, yielding 21.2 mds. (Std.) of first sugar. ..		
3 men for taking out **rab** from the tins	0 15 0	
2 men for mixing the **rab** with the hand (there being no pug-mill) and preparing charges for the centrifugal	0 10 0	

	Rs. a. p.	Rs. as. p.
Soda	0 1 0	
Ritha fruit (Sapindus Mukorossi) ..	0 2 0	
Firewood to boil the Ritha and water	0 2 0	
Grease	0 0 6	
	1 14 6	1 14 6
Miscellaneous Labour		
4 men for weighing cane	1 4 0	
6 men for the **Pata**	1 14 0	
	3 2 0	3 2 0
Boiling the molasses of the day's production, about 31.8 Standard Mds., yielding 26.8 Mds. of second rab.		
1 expert boiler	1 0 0	
1 labourer for airing and potting the **rab**	0 5 0	
1 boy for feeding the furnace.. ..	0 3 0	
1 labourer for carrying the molasses to the boiling-shed	0 5 0	
Fuel (bagasse used)	Nil	
	1 13 0	1 13 0
Machining the second rab 26.8 Mds. to yield 5.36 Mds. of second sugar.		
Centrifugalling	1 4 0	
Pata	1 4 0	
Working the engine for 8 hours ..	5 8 0	
	8 0 0	8 0 0
Permanent staff for supervision.		
Incidence of cost per day, the factory working for about 4 months in the year.		
1 Munib (Accountant and Assistant Manager) at Rs. 10/- per mensem with board.	2 0 0	
2 watchmen	2 0 0	
Pay of the Manager (not actually paid but here taken into account).. ..	6 0 0	
2 Orderlies	2 4 0	
	12 4 0	12 4 0
Depreciation.		
On machinery at 10%, the cost including shaftings and fittings being Rs. 11,000.	9 0 0	
On buildings at 5%	5 8 0	
	14 8 0	14 8 0

Cost of cane.	Rs.	as.	p.	Rs.	as.	p.
450 Mds. of cane at 8 annas per Md.	225	0	0			
Sundries, fuel, petty repairs to buildings and machinery.	3	12	9			
Contribution to a reserve fund to meet accidents.	10	0	0			
	238	12	9	238	12	9
Grand Total ..	300	0	0	300	0	0

The actual receipts from the sale of the daily output are enumerated below:—

21.2 Std. Mds. of first sugar at Rs. 48 per Palla (3½ Std. Mds.)	290	12	0
5.36 Std. Mds. of second sugar at Rs. 43 per Palla	65	13	6
21.44 Std. Mds. of second Molasses at Rs. 2-8-0 per Std. Md.	53	9	6
	410	3	0
Deduct expenses	300	0	0
Daily profit ..	110	3	0

This sum on a total outlay of Rs. 24,000. calculates to 45.8 per cent per annum of net profit, assuming the crushing season to extend over a hundred days, exclusive of a sum of about Rs. 1,000 credited to the reserve fund. No interest has been calculated as it seems unreasonable to expect double profits from the same capital. The reserve fund will bring in interest, if invested.

Now assuming that this factory was making superior **rab** under the system recently developed in Bhopal at a slightly higher cost of boiling (not exceeding Rs. 9-8-0 per diem), the expenditure per diem will amount to Rs. 309-8-0 but the yield of **rab** and sugar will be greater.

The **rab** from 275 Mds. of juice will be about 57.5 Std. Mds. instead of 53 Std. Mds. on account of less charring of the juice and wastage of the boiled material.

The produce will be :—	Rs.	as.	p.
First sugar 26.8 Std. Mds. (46.6% of the weight of **rab**) at Rs. 48 per palla	367	8	9
Second sugar (from 26 Std. Mds. of second **rab**) 8.5 Mds. at Rs. 43 per palla*	104	7	0
17.5 Std. Mds of molasses at Rs. 2-8-0 per Std. Md.	43	12	0
	515	11	9
Deduct expenses ..	309	8	0
.. .. .. Profit ..	206	3	9

*If the second **rab** is boiled in the auxiliary **bel** the second sugar resulting from it will not be worth less than Rs. 45 per palla.

The profit would then amount to 85.93 per cent per annum instead of 45.8 per cent, because the total yield of sugar from the **rab** boiled by the old Rohelkhand system which calculates to 5.9 per cent on the cane, will rise to 7.8 per cent under the new system.

Assuming further, that the competition with the foreign sugars became as keen as it did in the pre-war days and the price of the foreign material went down to Rs. 10/- per maund, it would be possible for the Indian **Khandsari** to hold his own in the competition as would appear from the following calculations of his income:—

	Rs.	as.	p.
First sugar 26.8 Mds at Rs. 10/- per Md. ..	268	0	0
Second sugar 8.5 Mds. at Rs. 8-8 per Md. ..	72	4	0
17.5 Mds. molasses at Rs. 2/8/- per Md. ...	43	12	0
	384	0	0
Deduct expenditure	309	8	0
Profit ...	74	8	0

This calculates to 31 per cent on the initial investment. The profits will be higher if more efficient mills are used for crushing and larger machines for centrifugalling. In the face of these figures there seems to be no reason whatever for the Indian manufacturer or the intending capitalist to be despondent regarding the future of the Indian Sugar Industry, if the simple improvements discussed in this book are adopted.

CHAPTER XVI.

Refining. (A) Manufacture of **Qand** (Loaf Sugar), Cube Sugar and Crystal Sugar (**Dane-dar shakar**).

The introduction of the centrifugal machine into the indigenous sugar industry has considerably facilitated the refining of **Khand** (first centrifugal-sugar), **galawat-ki-khand** (2nd sugar) and indeed all forms of low grade sugar into **Qand** which could easily be moulded into loaf sugar or cube sugar, or even be sold as white crystalline sugar, resembling the finer specimens of white sugar imported from Java and other sugar producing countries. Indeed, if the first sugar obtained is of inferior quality, it would generally be profitable to refine it. An inferior grade of first sugar would naturally be expected from the poorer quality **rab,** or when unbroken lumps (**rori**) of sugar have formed part of the magma treated in the centrifugal and remained imperfectly washed. If such lumps are broken and crushed, they yield a yellow powdery sugar which spoils the quality of the whole product. Such lumps should be removed by sifting, or better still a pug mill can be used to make a homogeneous mass of the crystallised **rab** before it is centrifuged.

For the indigenous method of manufacturing this form of sugar see page 93 of "The Sugar Industry of the United Provinces of Agra and Oudh."

To convert inferior sugar including the second sugar into refined crystalline white sugar (**Qand**), it is boiled with water and the syrup is clarified with milk till a perfectly clear syrup is obtained, which is then concentrated by continued boiling till the right consistency is attained. When ready to crystallise, the syrup is thinner than that of the cane-juice **rab** and the state is easily determined by the experienced eye of the boiler. The hot liquid is transferred into a round iron pan in which it is "aired" in order to favour crystallisation; as soon as the fine crystals become visible, the mass is transferred to kerosene tins to cool and crystallise further. After two or three days to crystallise the material is ready to be treated in the centrifugal. The sugar mass is tipped into an enamelled basin or brass or copper vessel, the hard lumps are broken with a wooden peg unless there is a pug mill for that operation, and put into the basket of the centrifugal, mixed, if necessary, with syrup eliminated from a previous charge to facilitate the machining.

It is only necessary to wash this sugar very sparingly with water injected by the syringe into the basket of the centrifugal machine. The spun sugar which is brilliantly white with a polarisation of 99 or over, is taken out, and if it is desired to make

lump or cube sugar, it is put into appropriate tin moulds whilst still moist, or it is dried in the sun and sieved to form crystal sugar. Lumps may be gently crushed in a stone grinding mill (**chakki**), but care should be taken neither to produce a mealy sugar nor a mixture of crystals of conspicuously varying sizes. No sugar known in the native industry can compare favourably with this product in respect of colour or crystal shape unless it has been prepared with Java or other foreign sugar as the basis. **Qand** (Loaf Sugar) has been manufactured in India for centuries past, but such uniformity of crystals or brilliancy of colour as is achieved by using the centrifugal, has never before been attained.

The scum, separated in course of clarifying the syrup with milk, is removed to a strainer which separates the excess sugar solution removed with the scum. This syrup is boiled into a slightly inferior quality of massecuite either separately or along with the syrup collected at the foot of the centrifugal during the spinning. In practice it has been proved more advantageous to convert all syrups so separated into the well known form of indigenous sugar called **bura** of which the method of preparation will be described presently.

The yield of refined sugar.

Two hundred pounds of inferior sugar (**Khand** and **rori** mixed) can be manipulated by a trained boiler in course of an ordinary working day with the single-pan boiling system. The total cost is about Rs. 2-12-0, or Rs. 1-6-0 per hundred lbs. of **Khand,** and the yield from 200 lbs. of inferior sugar is 105.5 lbs. of **Qand** and 89.5 lbs of **bura,** 5 lbs. 2.5 per cent being the loss incurred.

(B). Manufacture of Bura (crushed sugar).

By far the most popular form of Indian sugar, such as is used for sweet drinks and for general culinary purposes from the Western borders of Oudh to the west end of the United Provinces and further west in the Punjab is the one known as **bura.** The reason is that the principal white sugar of the West, the **Khand,** however clean and white it may be, has a more or less disagreeable flavour of molasses, and that flavour does not disappear until the **khand** has been re-boiled to make **bura.** Therefore, while it is good enough for preparing syrups or for manufacturing Indian sweets, the **khand** is never used at the table in its original raw condition. In the Eastern districts of the United Provinces and in Bihar a white sugar known as **pakki chini** is produced commercially from **gur** and not from **rab,** consequently **bura** is only sparingly manufactured if at all, as the **chini,** which is free from all suggestions

of molasses flavour, is available for table use. **Bura** is practically unknown in Bhopal where the native sugars used are the machine made sugars of the Cawnpore **swadeshi gur** refineries and the **pakki chini** of the Eastern districts of the United Provinces. In the **bura** tracts of the United Provinces, however, a new **bura** making industry has sprung up since the advent of foreign white crystalline sugar which owes its existence to downright fraudulent behaviour on the part of the manufacturer and to the credulity of his dupes, namely the people who refuse to use foreign sugar in their household on religious or sentimental grounds. Instead of boiling the true native **khand,** the fraudulent manufacturer boils foreign sugar mixed with a suitable proportion of **gur, potli** or the lowest grade of **khand.** The resulting **bura** which shows varying shades of yellow colour is passed as **bura** made from genuine **Swadeshi** sugar, or at any rate an attempt is made to get it passed as such and thus to obtain a higher price for the stuff than it is worth. When the improved processes in the manufacture of **khand** are adopted and the outturn secured is more than double of the yield obtained now under the **khanchi** system, the **bura**-maker of the new school will not have so much inducement to practice the fraud on which his business is based, and the lover of **swadeshi** will only then find that his real desire is fulfilled. Likewise, if the people in Bhopal and the neighbouring country extend the cultivation of sugarcane and establish small factories, the lower grade sugars produced therein and the **rori** which is practically unsaleable, will have necessarily to be converted into **bura** in order to turn those materials to good account, and the local industry will then become independent of the Cawnpore and the Benares sugars, which are at present imported. The manufacture of **bura** as an integral part of the scheme for the development of the native industry in Malwa with the use of the superior imported and acclimatised canes is an important matter, and should therefore receive the attention it deserves.

If the **rab** prepared is of good quality, such as that obtained from S.48 or P.O.J. 33 (**Lakhapur**) under the improved system, but a cetrifugal is not available, the crystals are separated by straining on a blanket or coarse cloth stretched on a bamboo frame. In a few hours the molasses will trickle and be collected into the receptacle below the frame, but the crystal sugar will of course never be as good as that obtained from a centrifugal treatment; still it could be boiled and converted into **bura** and so make an article which could be readily sold in the Indian market, and, indeed, it will be looked upon as a favoured saccharine product especially in the villages. Therefore a centrifugal is not essential to a revival of the native industry, but *the cultivation of richer and better canes is essential to produce sugar profitably.*

The basic raw material to be boiled for **bura**-making is the same inferior sugar as used for manufacturing **Qand,** which process has been already described. The syrup for **bura** however has to be boiled to a thicker consistency than for **gur, rab,** or **Qand;** and the right point upto which boiling should be continued requires a trained eye to decide. When ready, the pan is removed from the fire and the contents kneaded in a particular manner rather violently with wooden clubs of special construction known as **musad** by two men sitting opposite to each other on either side of the pan. When the mass has cooled down, it is reduced to a fine powder by rubbing with the bottom of a round earthen or brass vessel (**Handi** or **lota**). After being sieved, the powder is ready for the market. The lumps (**rori**) separated by the sieving are thrown into the next charge when ready for treatment with the **musad.** They may also be ground in a stone mill, sifted and the powder mixed with the **bura.** The loss of **khand** in the manufacture of **bura** varies with its purity, but in the Bhopal experiment it has ranged from 2.6 to 3 per cent.

CHAPTER XVII.

Annexed are reports from the two Sugar Chemists who helped the author in his research during the three Seasons:—

Report on the Sugar Cane Experiments carried out at Nuzhat Afza Farm, Bhopal, during the season 1924-25, particularly with reference to the chemical control of the work, by Mr. V. R. Mishra, L.Ag.

(A) Research Season 1924-25.

The main object of the work carried out at the Farm now in its third year of existence has been to determine to what extent the quality and the quantity of the **gur** and **rab** produced by the villager can be improved, whilst still maintaining the idea of a cottage industry in the State. Throughout, great care has been taken to avoid suggesting anything not within the scope of the cultivator or an easy adoption of local practice in the manufacture of **gur** and **rab.** The advance made in this work was so great that it has been possible more recently to make white sugar and to consider its manufacture here also.

The indigenous canes grown locally are rather poor in appearance. Numerous varieties of canes from different parts of India have been collected, and it is now possible to make a preliminary selection of these varieties which appear to be most suited to the local conditions of soil, water and climate, having regard to :—

(1) early and vigorous growth with and without irrigation,
(2) strong root system,
(3) early ripening,
(4) erect habit,
(5) resistance to disease,
(6) sugar value, i.e. yield of cane, juice and sucrose per acre.

It is appreciated that it is the work of many seasons to make a final judgment as to the local suitability of any particular cane owing to the numerous controllable factors, but some canes, notably S.48, stand far above the others.

The laboratory determinations usually made were :—

1. Sucrose per 100 parts of juice
2. Sucrose „ „ bagasse
3. Sucrose „ „ cane
4. Purity of juice
5. Percentage of sucrose in **gur**
6. Polarisation of sugars

In the milling yard, a careful note was made of the yield of juice per 100 parts of cane, which, when coupled with the above analyses, gave such interesting figures as the yield of sucrose (as juice) per 100 parts of sucrose (as cane).

The efficiency of the milling depends very much on the quantity and the kind of fibre of which the cane is built up. No satisfactory quantitative determination of this matter could be made, although there were obvious differences between the varieties.

Generally all the varieties of cane at the Farm flowered this year and it was found that the flowered canes invariably gave a higher sucrose content than the unflowered ones.

A close study was made of the changes in sucrose content of the canes, by varieties, week by week from December to March. These figures are collected in the table attached, and show the expected maximum and the subsequent fall in value. Some variation was expected and found in the results obtained from the same variety on different plots of ground. It is impossible to correlate this variation with the factors producing it, except to observe that the more healthy looking the crop, the higher the yield of sucrose obtained from it. This was the case with S. 48 canes on plots 5, 6 and 12, No. 6 being better than the others.

Cloudy weather and rains affect the sucrose content of the cane. This season, the unsettled weather continued from about December 10th to 19th, when the cane was unripe. Consequently, there was only a slight fall in the sucrose content when the canes were analysed immediately after the rainy period. Had the sucrose content of the cane been higher at the time; a greater effect would have been expected. This condition suggests that it might be desirable to suspend irrigation of a crop some weeks before harvesting.

As was to be expected, the basal portions of the cane were richer in sucrose than the upper or growing portion of it. The tops were, therefore, cut off for sowing, leaving a richer raw material for the subsequent extraction processes. This condition was particularly noticed when preparing raw sugar (**kachha bura**) directly from the juice. When the crop was fully mature, such raw sugar was prepared quite easily from practically the whole cane, only a few inches of the topmost section being removed. As the season advanced and the sucrose content began to fall, much more had to be rejected to secure equivalent results. The variety which proved most successful for this work over the longest period was S.48 only, although Co. 214 and Co. 221 were good.

For the same reason, during harvesting, care should be taken to cut the cane as closely as possible to the ground.

After cutting, the sugar content of the cane begins to fall at once, not only as to the absolute quantity of sucrose but also in the degree of purity of sucrose in the juice expressed from the cane. This result is very strongly marked in canes after lying in the sun for 24 hours and to a lesser extent in canes stacked in the shade.

It is, therefore, necessary to crush the cane as quickly as possible after cutting, whether it be for central factory or cottage industry, and only the day's requirements should be harvested.

The quantity and nature of the organic non-sugar substances in the juice vary considerably, depending upon the variety and age of the plant and the degree of expression of the juice. These substances, as is well known, affect the yield of crystallisable material to be obtained and their removal by the process of clarification is therefore very important. (Even when the clarification is complete, there is still a difference between the percentage of sugar as determined by the polarimeter and as deduced from the specific gravity of the liquid: this is mostly the invert sugar.)

For example, some difficulty was experienced with the clarification of the juice from the unripe Yuba cane, the **rab** of which gave a sugar of rather a gummy nature which did not centrifuge with accustomed ease. This trouble was avoided by a partial liming, taking care to keep below the neutral point or the brilliance of the sugar was impaired. It was also found that cautious liming tended to increase the sugar yield.

The **rab** or **gur** from an iron pan was always found to be darker in colour than from a brass pan, and from the same brass pans, the green coloured canes always gave a brighter product than the dark red canes.

Note on a Possible Mutation or Variation in Striped Mauritius Cane.

From a clump of Striped Mauritius canes, green sports appeared of the same or even better thickness, height and vigour than the original cane. These were isolated and sown separately. At the same time, dark red canes were found in the same field but never associated with the striped Mauritius in a clump. These dark canes were probably a stray variety and in any case they appeared to be of low chemical value.

Note on Non-irrigated Canes.

Trials of different varieties of cane under different conditions are going on, but no account of them can be given at present except to say that so far Co. 221 and Yuba are doing well and even better than S.48 and Co. 214 which is fairly good. P.O.J. 33 did well for the first few months after it was sown but later it exhibited bad symptoms.

Naturally the yield of a dry cane per acre is always less than that of an irrigated one. From Appendix 2 it will be seen that when examined in February the percentage of sucrose in the juice of S. 48 and Yuba under dry conditions is greater than that when sown under irrigation, but it is necessary to consider the result in conjunction with the yield of sugar per acre, seeing that the extraction of juice from an unirrigated cane is always less than that from an irrigated one.

Appendix III. Analysis of rab.

Serial no.	Variety.	p.c.Sucrose in **rab.**	Brix	Purity.
1	S. 48	80.68	94.35	85.51
2	P.O.J. 33	74.23	91.98	80.70
3	Yuba	71.17	89.70	79.34

Appendix IV. Analysis of gur.

Serial no.	Variety.	p.c. sucrose in **gur.**
1	S. 48	82.82
2	Co.214	78.10
3	Co.221	77.80
4	P.O.J. 33	76.50
5	Yuba	72.80

The amount of sucrose in **rab** and **gur** depends upon the degree of inversion brought about by the boiling which in turn depends upon the nature and quantity of the natural acids present originally in the juice as well as on the period for which the juice is boiled.

Prolonged slow boiling of the juice tends to lower the sucrose content in **rab** and sugar, hence care should be taken to prepare them as rapidly as possible.

Appendix V. Polarisation.

1st sugar	97.92
2nd sugar	88.7 *
Qand (refined sugar)	99.07
Bura from 2nd sugar	86.40
Final molasses	35.7

Methods of Analysis Employed.

1. Juice.

Brix or total solids:—The degree Brix is the percentage by weight of sucrose in a pure sugar solution. But in the sugar industry it is a common practice to consider the degree Brix as the percentage of solid matter, or the total solids dissolved in the liquids. The less the amount of impurity present, the more nearly is this reading the true percentage of sugar.

Determination of Brix:—A Brix hydrometer verified at 17.5°C is floated in cane juice inside a glass cylinder of about 300 c.c. capacity. After sometime when the hydrometer and the juice are at the same temperature, the temperature is taken and the scale of the hydrometer is immediately read and the latter corrected from the reading of the thermometer, using table given below :—

In subsequent research seasons the polarisation of the second sugar rose very considerably as a result of successive improvements in the method of manufacture, vide Table VIII page 239 and Table XXII page 281.

TEMPERATURE CORRECTIONS BRIX HYDROMETER GRADUATED AT 17.5°C

Page No. 222-223.

Degrees

	0	5	10	15	20	25
Temperature.				Sub	tract Fr	om The
15	0.09	0.11	0.12	0.14	0.14	0.15
16	0.06	0.07	0.08	0.09	0.10	0.10
17	0.02	0.02	0.03	0.03	0.03	0.04
Temperature.					Add	To The
18	0.02	0.03	0.03	0.03	0.03	0.03
19	0.06	0.08	0.08	0.09	0.09	0.10
20	0.11	0.14	0.15	0.17	0.17	0.18
21	0.16	0.20	0.22	0.24	0.24	0.25
22	0.21	0.26	0.29	0.31	0.31	0.32
23	0.27	0.32	0.35	0.37	0.38	0.39
24	0.32	0.38	0.41	0.43	0.44	0.46
25	0.37	0.44	0.47	0.49	0.51	0.53
26	0.43	0.50	0.54	0.56	0.58	0.60
27	0.49	0.57	0.61	0.63	0.65	0.68
28	0.56	0.64	0.68	0.70	0.72	0.76
29	0.63	0.71	0.75	0.78	0.79	0.84
30	0.70	0.78	0.82	0.87	0.87	0.92
35	1.10	1.17	1.22	1.24	1.30	1.32
40	1.50	1.61	1.67	1.71	1.73	1.79
50		2.65	2.71	2.74	2.78	2.80
60		3.87	3.88	3.88	3.88	3.88
70		5.17	5.18	5.20	5.14	5.13
80			6.62	6.59	6.54	6.46
90			8.26	8.16	8.06	7.97
100			10.01	9.87	9.72	9.56

HYDROMETER GRADUATED AT 17.5°C

Brix.

30	35	40	50	60	70	75
Observed	Reading.					
0.16	0.17	0.16	0.17	0.19	0.21	0.25
0.11	0.12	0.12	0.12	0.14	0.16	0.18
0.04	0.04	0.04	0.04	0.05	0.05	0.06
Observed	Reading.					
0.03	0.03	0.03	0.03	0.03	0.03	0.02
0.10	0.10	0.10	0.10	0.10	0.08	0.06
0.18	0.18	0.19	0.19	0.18	0.15	0.11
0.25	0.25	0.26	0.26	0.25	0.22	0.18
0.32	0.32	0.33	0.34	0.32	0.29	0.25
0.39	0.39	0.40	0.42	0.39	0.36	0.33
0.46	0.47	0.47	0.50	0.46	0.43	0.40
0.54	0.55	0.55	0.58	0.54	0.51	0.48
0.61	0.62	0.62	0.66	0.62	0.58	0.55
0.68	0.69	0.70	0.74	0.70	0.65	0.62
0.76	0.78	0.78	0.82	0.78	0.72	0.70
0.84	0.86	0.88	0.90	0.86	0.80	0.78
0.92	0.94	0.94	0.98	0.94	0.88	0.86
1.33	1.35	1.36	1.39	1.34	1.27	1.25
1.79	1.80	1.82	1.83	1.78	1.69	1.65
2.80	2.80	2.80	2.79	2.70	2.56	2.51
3.88	3.88	3.90	3.82	3.70	3.43	3.41
5.10	5.08	5.06	4.90	4.72	4.47	4.35
6.38	6.30	6.26	6.06	5.82	5.50	5.33
7.83	7.71	7.58	7.30	6.96	6.58	6.37
9.39	9.21	9.03	8.64	8.22	7.76	7.42

Determination of Sucrose in juice:—A small flask (100-110 c.c. calibrated) is filled with the juice to the 100 c.cs. mark; then 3 c.c. of a solution of subacetate of lead* is added and the contents made up with water to the 110 c.c. mark; the whole is then well shaken, filtered, and polarised in the 200 m.m. tube. To compensate for the dilution from 100 c.cs. to 110 c.cs., increase the polarisation figure by one-tenth to get the direct polarisation value. Then 50 c.c. of the same clarified juice are placed in a 100 c.c. flask with 5c.c. of hydrochloric acid (of 1.188 specific gravity) and about 20 c.c. of water. Place the flask in a water-bath heated to about 70°C and allow the temperature of the solution in the flask to reach 68°C in three to five minutes and continue the heating during a total period of 10 minutes. The flask is then rapidly cooled to the laboratory temperature the thermometer which had been placed in the liquid carefully rinsed and removed and the contents filled upto the mark and then polarised in a 200 m.m. tube. Again compensate and get a true reading of the invert polarisation by multiplying the reading by two, and increasing the total by one-tenth. Directly after polarisation observe the temperature of the fluid.

The number of grammes sucrose per 100 c.c. is found by the formula :—

$$\frac{(\text{Direct polarisation} - \text{invert polarisation}) \times 26.048}{142.66 - \frac{t}{2}}$$

where t equals temperature of the invert reading in degrees centigrade.

Determination of Coefficient of purity :—The coefficient of purity of juice, massecuites, molasses, sugars, etc., is the percentage of sucrose in the total solid matter of the product.

The coefficient which is generally calculated in the sugar industry is the apparent coefficient.

---

* Subacetate of Lead:-Prepare by boiling 430 grm. of normal lead acetate, 130 grms. of litharge, and 1,000 c.c. of water for half an hour. Allow the mixture to cool and settle and dilute the supernatant liquid to 54.3 Brix (i.e., Sp. Gr. 1.2536) with water.

The volume of the above solution required to clarify the known volume of the juice from the different varieties of cane varies greatly; hence only that much minimum amount of it should be used for each variety which would give facility to an observer in matching the fields of illumination while taking polarisation. This can be achieved with a little practice. Excessive amount of the above solution gives a high polariscopic reading.

This apparent coefficient of purity is equally taken as the ratio of the direct polarisation to 100 parts of the apparent solids as calculated from the degree Brix :—

$$\text{Apparent co-efficient of purity} = \frac{\text{Direct polarisation} \times 100}{\text{total solids by degrees Brix}}$$

or sometimes the true percentage of sucrose as determined by double-polarisation method is used in calculating the apparent coefficient of purity in which case :—

$$\text{Apparent coefficient of purity} = \frac{\text{\% of sucrose by inversion}}{\text{total solids in degrees Brix.}} \times 100$$

One should carefully distinguish between the apparent and the true co-efficient of purity. The true co-efficient of purity is the percentage of actual sucrose in the total solid matter as estimated by the method of drying. This can be determined in the following way :—

$$\text{True co-efficient of purity} = \frac{\text{Sucrose by the inversion method}}{\text{Total solids by actual drying}} \times 100$$

(2) Bagasse.

Determination of sucrose in bagasse—20 grammes of the finely divided bagasse is weighed in a metal beaker. 250 c.c. of water are added to it and then the whole is boiled. A 50 c.c. pipette is fixed over the boiling vessel and water from it is allowed to trickle through a rubber tube, closed with a pinch cock at such a rate that the addition of water keeps pace with the evaporation. The addition of water is started as soon as the liquid boils and is continued through the whole boiling period, that is for about a quarter of an hour. The amount of water added is adjusted so that at the end of the operation the volume is about 250 c.c. The beaker is then cooled and 5c.c. of subacetate of lead solution are added; then the whole is weighed, and contents well stirred and filtered, the filtrate being polarised in a 200 m.m. tube and the reading multiplied by 2.

The amount of water added is found by subtracting the weight of the beaker with the bagasse from the ultimate weight of the beaker with its contents after being cooled. In this weight of liquid we must reckon also the weight of the juice contained in the bagasse itself, which is taken to be 55% or 11 grammes.

The percentage of sucrose is found from the table given below :—

Table for determination of the sucrose content of bagasse from the polariscope reading and the weight of the extract.

$$\text{Sucrose} = \text{Polarimeter Reading} \times \frac{26.048}{20} \times \frac{\text{Sp. Gr.}}{100} \times \tfrac{1}{2}.$$

Polariscope reading in the 400 mm. Tube.

Weight of juice in grms.	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
200	2.59	2.72	2.85	2.98	3.11	3.24	3.37	3.50	3.63	3.76	3.90
205	2.66	2.80	2.92	3.05	3.19	3.32	3.46	3.59	3.72	3.85	3.99
210	2.72	2.87	3.00	3.13	3.27	3.40	3.54	3.68	3.81	3.95	4.09
215	2.79	2.93	3.07	3.20	3.34	3.48	3.62	3.76	3.90	4.04	4.19
220	2.85	3.00	3.14	3.28	3.42	3.56	3.70	3.85	4.00	4.14	4.29
225	2.91	3.07	3.21	3.36	3.50	3.65	3.80	3.94	4.09	4.23	4.38
230	2.99	3.14	3.28	3.42	3.58	3.72	3.88	4.02	4.18	4.33	4.48
235	3.05	3.20	3.36	3.50	3.67	3.81	3.97	4.11	4.27	4.42	4.59
240	3.11	3.28	3.43	3.58	3.73	3.90	4.06	4.20	4.37	4.51	4.68
245	3.18	3.34	3.50	3.65	3.81	3.97	4.13	4.29	4.45	4.60	4.78
250	3.24	3.40	3.57	3.73	3.90	4.06	4.21	4.38	4.55	4.70	4.88
255	3.31	3.48	3.64	3.80	3.98	4.14	4.30	4.48	4.64	4.80	4.98
260	3.38	3.55	3.71	3.88	4.05	4.22	4.39	4.57	4.73	4.90	5.07
265	3.44	3.61	3.79	3.96	4.13	4.30	4.47	4.66	4.82	4.99	5.17
270	3.51	3.68	3.86	4.03	4.20	4.39	4.55	4.75	4.91	5.08	5.27
275	3.58	3.75	3.93	4.10	4.29	4.47	4.63	4.84	5.00	5.18	5.37
280	3.64	3.82	4.00	4.18	4.36	4.55	4.72	4.93	5.10	5.27	5.46
285	3.70	3.89	4.08	4.26	4.44	4.63	4.80	5.02	5.19	5.37	5.56
290	3.78	3.96	4.15	4.33	4.52	4.71	4.90	5.11	5.28	5.46	5.66
295	3.84	4.02	4.22	4.41	4.60	4.79	4.97	5.20	5.37	5.55	5.76
300	3.90	4.10	4.29	4.48	4.68	4.87	5.06	5.30	5.46	5.65	5.86

Polariscope reading in the 400 mm. Tube.

Weight of juice in grms.	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0
200	4.02	4.15	4.28	4.41	4.54	4.68	4.80	4.95	5.08	5.21
205	4.12	4.26	4.39	4.52	4.66	4.80	4.92	5.07	5.20	5.34
210	4.22	4.36	4.50	4.64	4.78	4.91	5.04	5.19	5.33	5.46
215	4.32	4.47	4.60	4.75	4.89	5.04	5.16	5.32	5.46	5.60
220	4.42	4.57	4.71	4.86	5.00	5.15	5.28	5.44	5.58	5.73
225	4.52	4.67	4.81	4.97	5.11	5.27	5.40	5.56	5.71	5.86
230	4.62	4.78	4.92	5.08	5.23	5.39	5.53	5.69	5.84	6.00
235	4.72	4.89	5.04	5.20	5.34	5.51	5.64	5.81	5.96	6.12
240	4.83	5.00	5.15	5.30	5.45	5.61	5.77	5.94	6.09	6.25
245	4.93	5.09	5.24	5.40	5.56	5.72	5.88	6.06	6.22	6.38
250	5.03	5.19	5.35	5.51	5.68	5.84	6.00	6.18	6.34	6.51
255	5.13	5.29	5.46	5.62	5.79	5.96	6.14	6.31	6.47	6.64
260	5.23	5.40	5.57	5.73	5.90	6.08	6.26	6.43	6.60	6.77
265	5.33	5.50	5.67	5.85	6.02	6.20	6.37	6.55	6.73	6.90
270	5.43	5.60	5.78	5.96	6.13	6.30	6.49	6.68	6.85	7.03
275	5.53	5.70	5.89	6.07	6.25	6.42	6.60	6.80	6.97	7.16
280	5.64	5.81	6.00	6.18	6.36	6.54	6.73	6.92	7.11	7.29
285	5.74	5.91	6.10	6.29	6.48	6.66	6.84	7.05	7.23	7.42
290	5.84	6.02	6.21	6.40	6.59	6.78	6.97	7.17	7.36	7.55
295	5.94	6.12	6.32	6.50	6.70	6.90	7.10	7.30	7.49	7.68
300	6.04	6.23	6.43	6.63	6.81	7.01	7.20	7.42	7.61	7.81

Calculated for 20 grms. of bagasse and about 300 c.c. of water.

(3) Massecuites.

Brix :—In the case of massecuites the degree Brix is determined in a manner slightly different from that used in the case of juice; the reason being, first, that massecuites are too dense to be directly spindled, hence one must accept numbers obtained by dilution and spindling, and secondly, in order to effect a good comparison of the coefficients of purity of the juices and the massecuites, it is advisable to determine the degrees Brix in about the same concentration in both cases. To do so the massecuite is diluted with four times its weight of water, the degree Brix determined, the result being corrected for temperature variation and multiplied by 5 to bring the reading to the original strength.

The results thus obtained must not be considered absolute, but only as suitable for the sake of comparison. The true Brix is several degrees lower than the apparent number obtained as described above.

Determination of Sucrose in rab. (Massecuites) — The normal weight (26.048 grms) of the sample to be examined is dissolved in about 75 c.c. of water in a 100 c.c. flask, 5 c.c. of a solution of subacetate of lead is added and the volume is made up to the 100 c.c. mark. The liquor is well shaken, filtered and polarised in a 200 m.m. tube the result giving the direct polarisation. 50 c.c. of this solution is transferred to a 100 c.c. flask, for inversion by means of hydrochloric acid exactly as was discussed for the determination of sucrose in juice.

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* (1) When 100 c.c. of the juice are diluted to 110 c.c. and read in a 200 m.m. tube, multiply the polariscopic reading by 11/10 or increase the observation tube by one-tenth, i.e. use 220 m.m. tube. The greater the length of the observation tube the greater the reading. Reading varies directly as the length of the tube.

(2) The greater the concentration of the solution the greater the reading. Reading varies as the concentration.

(3) Reading decreases as the temperature increases

From the direct and invert polarisation figures the percentage of sucrose is found in the sample by the following formula :—

$$\frac{(\textbf{Direct polarisation—invert polarisation}) \times 100}{142.66 - \frac{t}{2}}$$

where t equals temperature of the invert reading in degrees centigrade.

(4) **Determination of Sucrose in molasses and sugars** :—This is determined exactly in the manner described for the case of massecuites.

Extraction :—By extraction we mean the amount of cane juice calculated in an undiluted state extracted on 100 parts of cane by weight. This figure is much influenced by the fibre content of the cane, the greater the amount of fibre present the less the extraction and also the greater the loss of juice.

The quality of juice expressed without dilution is dependent on the pressure of the mill. Juice extracted with a heavy pressure is of an inferior quality to that with a light one. For this reason some people extract juice with dilution.

In Hawaiian Islands, the term extraction means the percentage of sucrose in the cane that is obtained in the mixed juices and is calculated from the following formula :—

$$\textbf{Per Cent Extraction} = \frac{\text{Per cent Sucrose in mixed juice} \times \text{weight of mixed juice}}{\text{Per cent Sucrose in cane} \times \text{weight of cane}} \times 100$$

Glucose Co-efficient :—This is calculated as follows :—

$$\textbf{Glucose Co-efficient} = \frac{\text{Per cent Glucose.}}{\text{Per cent Sucrose.}} \times 100.$$

Saline Co-efficient :—The Saline Co-efficient is the quantity of sucrose per unit of ash. It is calculated as follows :—

$$\textbf{Saline Co-efficient} = \frac{\text{Per cent Sucrose}}{\text{Per cent Ash.}}$$

Available Sugar :—Several factors govern the amount of sugar that may be considered available in the mill-juice,

viz. :— (i) The efficiency of the machinery,
(ii) The quality of the juice,
(iii) and the skill of the factory superintendent,

The quality of the juice depends upon its richness and the nature of its impurities. The same variety of cane as mentioned previously, grown on different plots varied in their richness and purity. The recovery of sugar varies with the co-efficient of purity of the juice and the losses in manufacture.

Available sugar estimates are necessary when cane is purchased on a basis of its analysis. The following formula by Winter and Carp works well under tropical conditions :—

X=available sucrose per cent cane;
S=per cent sucrose in the juice in terms of the weight of the cane
C=Coefficient of purity of the juice

$$\therefore \quad X = S \times \left(1.4 - \frac{40}{C}\right)$$

To calculate the available sucrose in terms of the available sugar, divide the value of X by the polarisation of the sugar and multiply the quotient by 100.

The second part of the formula, $100 \times \left(1.4 - \frac{40}{C}\right)$ gives the "recovery" number, and this number divided by 0.96 gives the recovery in 96° Sugar. The figure 96° polarisation is generally obtained in raw sugar in regular working and hence it is used as the basis in working out calculations.

Calculation of Rendement :—The calculation of the refining value, "net analysis", or rendement of raw sugars in a Sugar Industry is an essential one. The rendement is the yield of pure crystallised sucrose which can be obtained from a raw product. Monnier in France in 1863 assumed that 1 part of mineral impurities prevented the crystallisation of 5 parts of sucrose, and so calculated the yield of crystallisable sugar by subtracting 5 times the percentage of ash from the polarisation of the raw product. For cane sugars the following formula is used.

Rendement = Polarisation—(5 × %ash + % invert sugar).

This formula is more used in other countries than in France. The common method in France is to subtract from the polarisation four times the percentage of ash and twice the percentage of invert sugar; from this remainder 1.5 per cent additional is then deducted as the loss in refining. In 1893 the German Refiners' Association introduced a method for calculating rendement which consisted in multiplying the percentage of total non-sugars by 2¼ and subtracting the product from the polarisation. This "non-sugar yield" was found, however, to be less satisfactory than the "ash yield" and the return was made to the old method of Monnier.

Further Methods of Analysis employed,

by

J. K. Dubey, M.Sc., M.A.C.S., F.S.T.A. Etc.

Research Season 1925-26.

Determination of Reducing Sugars. In practice 100 c.c. of cane juice are taken for Sucrose analysis, clarified with basic lead acetate, made to 110 c.c. by addition of distilled water, filtered and sucrose determined, as described by Mr. Misra in the foregoing pages, of this filtrate take 50 c.c. for inversion and to the remainder add 3 grammes of powdered sodium carbonate and 3 grammes of sodium phosphate, just enough to complete the precipitation of lead, stir it and allow to stand for some time. Now filter the juice rejecting the first three c.c. and fill it into a burette. Take exactly 10 c.c. each of half normal Fehling's Solution no. I and II in a porcelain dish and dilute it with 60 c.c. of distilled water, raise the mixture rapidly to boiling point. Now run the sugar solution from the burette slowly into the boiling mixture, agitating continually, until all the copper is precipitated as cuprous oxide. The end point is noted as the colour of the solution gradually changes from blue to almost colourless, and the solution finally begins to turn yellow. The end of the reaction to be sure of it is found as follows :—Three pieces of filter paper placed one on the other are taken and moistened in the centre with a drop or two of the solution from the porcelain dish. When the third paper is moist the first two are rejected and a drop of potassium ferrocyanide (20 grammes in 1000 c.c. of water) is placed on the moist part of the paper and then a drop of 10% acetic acid. If there is even a trace of copper a distinct red coloration appears on the paper; if there is no coloration the reaction is complete.

The percentage of reducing sugars is calculated in this way :—

$$\text{R.S.\%} = \frac{5.5}{\text{No. of c.c. sugar solution used.}}$$

Note. 5.5 needs an explanation. 10 c.c. of half normal Fehling's Solution no. I is equal to 0.05 gms of glucose. Therefore 110 c.c. of sugar solution if it had only glucose present in it will be equal to $110 \times 0.05 = 5.5$ grammes.

In the determination of reducing sugars in **rab** instead of taking the clarified sugar solution it is diluted with four times its volume of distilled water and then used for titrating against Fehling's Solution as described above. In calculating reducing sugars the c.c. of sugar solution are calculated to the equivalent of the original solution and then the following formula is used :—

$$\text{R. S.\%} = \frac{5.5 \times 100}{\text{c.c. of sugar solution} \times 26.048}$$

Total solids in gur or rab.

10 gms of a homogenous sample are weighed in a tared aluminium dish and dried in an oven until the weight is constant. The loss in weight represents moisture and the residue real total solids.

Ash in gur or rab. 5 gms of a homogenous sample are weighed in a tared crucible to which one cubic centimetre of strong sulphuric acid is added. The crucible is kept in the water oven for about half an hour, when the sample becomes black and swelled. It is then heated on a low flame and finally on a high flame, until all the carbon has volatilised. It is then removed from the flame, put into a dessicator, when just warm enough to touch, cooled and weighed. Now one tenth of the weight obtained is deducted for the amount of sulphuric acid used. The percentage of ash is then obtained by simple calculation.

Fibre in cane. 20 gms of a chopped sample of bagasse are weighed, placed in a linen cloth and tied well so that the fibre will not fall down. The sample is soaked in water cloth and all, pressed in a book-binder's press, again soaked in water and again pressed. This operation is repeated 6 to 7 times. By this time all the sugar and other soluble compounds have been removed, the sample is then placed in the oven dried and weighed. The residue left represents the amount of fibre in 20 gms of bagasse.

Preparation of Reagents.

Preparation of basic lead acetate. Boil 430 gms of lead acetate and 130 gms of litharge in 1000 c.c. of distilled water until all the litharge disappears. Allow the solution to cool and the oxides to settle down, then decant and dilute with recently boiled distilled water to requisite specific gravity. (54.3° Brix.)

Preparation of half normal Fehling's Solution. Solution No. I. Dissolve exactly 34.639 gms of chemically pure copper sulphate into distilled water and dilute it to 1000 c.c.

Solution No. II. Dissolve 173 gms. of pure sodium-potassium tartrate (Rochelle Salt) in distilled water. To this add 100 c.c. of pure sodium hydroxide solution containing 516 gms. of sodium hydroxide per litre. Make the whole to 1000 c.c.

Solutions No. I and II are kept separate and should be mixed in equal volume immediately before use.

CHEMICAL NOTE,

by

J. K. DUBEY, M.Sc., M.A.C.S., F.S.T.A. etc.,

B. Research Season 1925-26.

When the writer began his work in the Agricultural laboratory late in 1925, there was unfortunately with the exception of a polarimeter, practically no apparatus in it. He had, therefore, to confine himself to such simple determinations as sucrose in juice and sucrose in bagasse. He was given greater facilities in 1926-27 and would refer his readers in addition to the information they obtain from this note to his work for that year, to obtain more comprehensive information on all the changes which the sugarcane undergoes during the period of its growth and maturity, when it is finally crushed and the juice is converted into **rab** or **gur.**

The research work which is being continued at the Government Agricultural Farm, Bhopal, with a view to the finding of varieties of cane most suitable for the Malwa climate and for the making of all-round improvements in the methods of cultivation and crushing of cane, and of boiling the juice, has now reached a definite stage of development and the results obtained during this season, especially from a chemical point of view, are described in the following pages.

A wide range of canes was required to meet all the conditions of soil and climate in Malwa and special methods of selection and investigation had to be devised to meet these conditions at a minimum cost and in as short a period of time as possible. The following lines of investigation were therefore followed:—

1. Study of local canes.
2. Importation of canes from other parts of India.
3. Investigation of Coimbatore seedling canes.

All the local canes, on analyses in the chemical laboratory, were found to be low in sucrose content, and by outturn tests in the field to be poor in tonnage yield. Of exotic and imported varieties S.48, P. O. J. 33, Manjav, White Transparent, and 247B have proved excellent for the Malwa climate. Of Coimbatore seedlings Co. 214 and Co. 221 have given very satisfactory results. Co. 205, Co. 210, Co. 213, and Co. 281 are still on trial and no definite opinion can be given on their merits.

All the above canes have good germination, splendid vigour and fine resistance to disease. S. 48 and some of the seedling canes were, however, badly attacked by Chilo Simplex during the extraordinarily hot summer of 1926, but regained their vigour as soon as the rainy season had commenced.

The early cessation of rains during 1925 also affected the growth of standing crops, and they had to be irrigated by well water, but the deficiency in rainfall became more clearly evident when it came to actual tonnage weight. The canes grew to a good height but did not become so thick as in an average year, and it was found that however well a cane might withstand drought the final outturn was linked to the rainfall distributed over a wide period of time.

A continuous downpour of rain for a long period of time also stunts and retards the growth of standing crops, making the soil water-logged and stopping aeration.

The maturity of the cane was hastened by the drought of 1925, and the crops, which would normally be dealt with in January and February had to be dealt with much earlier, for fear of over-ripening and consequent deterioration in sugar contents.

Seedling canes which profusely flowered last year did not flower this year. A few hundred stalks which did flower contained a higher percentage of sucrose than was found in the canes of the same variety, which had not flowered, when the two samples were taken from the same stool and analysed on the same date.

TABLE 1.

Variety of cane.	Date of analysis.	Flowered or not flowered.	Sucrose in juice. %	Brix of juice.	Purity
Co. 221	25-12-25	Flowered	18.21	21.6	84.31
,,	,,	Not flowered	17.48	21.4	81.68
,,	21-1-26	Flowered	18.93	22.4	84.51
,,	,,	Not flowered	18.92	22.36	84.61
,,	10-2-26	Flowered	18.94	22.4	84.55
,,	,,	Not flowered	18.94	22.4	84.55
Co. 214	26-11-25	Flowered	15.80	18.8	84.04
,,	,,	Not flowered	15.53	18.6	83.49
,,	24-12-25	Flowered	16.10	18.8	85.64
,,	,,	Not flowered	16.05	18.8	85.37
,,	10-1-26	Flowered	16.21	19.0	85.32
,,	,,	Not flowered	16.20	19.0	85.26

It will be seen from the above table that the flowered canes not only had higher sucrose content and greater purity than the unflowered ones but that they continued to gain in sugar for about a month. The unflowered canes, however, caught up with the flowered ones at the end of a month, the latter showing practically no signs of deterioration even a fortnight after this period.

One thing which may, however, be said against flowering is that when a cane flowers, its growth is stopped and no amount of irrigation or any other artificial measures adopted to stimulate growth would probably be of any use. It cannot be left in the field longer than a month and a half and it should preferably be crushed even before this period, if the crop is a large one.

Great damage to the standing crops was done by Pseudo coccus Saccharalis. Rats also played great havoc. The only way to partly redeem the loss caused by the rats is to immediately collect the damaged canes, cut them into sets and plant in a separate area. Sets so planted germinated remarkably well and formed one of the best crops standing on the farm.

A serious wind and rain storm early in February badly affected the standing crop and a serious lodging with consequent loss in sucrose content took place. Some of the thick canes such as P.O.J. 33 and Manjav, however, showed signs of lodging as early as 25th January. It is, therefore, very essential that such canes should receive extra heavy earthing up. This subject has been fully dealt with in the note on the research work during 1926-27 and the reader is referred to it.

In table II are given the figures showing the monthly variations in the sucrose contents of exotic and seedling canes. Of all the imported varieties S. 48 was found to contain the highest percentage of sucrose and had the highest purity, while **Nasik-khadia** had the least sugar and the lowest purity.

TABLE II.

Analyses of Irrigated exotic and imported canes.

Variety of cane.	November 1925.				December 1925.				January 1926.				February 1926.			
	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %
S. 48	16.35	19.20	85.16	5.60	16.88	19.50	86.56	5.71	18.89	21.35	88.47	5.82	19.46	21.90	88.86	6.70
Co. 213	15.15	18.00	84.17	5.81	16.14	18.92	85.36	5.92	17.21	19.46	88.44	6.18	17.81	20.10	88.61	6.83
Co. 214	15.80	18.80	84.04	6.21	16.10	18.80	85.64	6.82	16.22	19.05	85.14	6.97	Not determined			
Co. 221	16.26	18.98	85.67	5.76	17.48	20.05	87.18	5.86	17.65	20.20	87.38	6.41	18.01	21.00	85.76	6.88
Manjav	15.20	18.00	84.44	8.10	17.40	19.80	87.88	8.46	18.65	21.10	88.39	8.54	19.20	21.70	88.48	8.71
Lakhapur (P.O.J. 33)	16.26	19.00	85.58	8.15	17.16	19.88	86.32	8.23	17.46	20.00	87.30	8.46	16.89	19.46	86.79	8.21
Nasik Khadia	9.90	14.10	70.21	8.12	10.12	14.29	70.89	8.21	11.10	15.00	74.00	8.38	Not determined			

TABLE III.

Analyses of Irrigated indigenous canes.

Variety of cane.	November 1925.				December 1925.				January 1926.				February 1926.			
	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %
YUba	10.80	15.00	72.00	6.01	12.10	16.80	72.02	6.09	13.85	17.90	77.37	0.18	Not determined			
Dhaul	10.30	15.20	67.76	5.81	10.81	15.82	68.33	5.82	13.12	15.93	82.36	5.91	14.38	17.20	83.60	6.42
Munhtora	10.90	15.00	72.67	5.60	11.91	16.20	73.52	6.28	14.81	17.60	84.15	6.82	14.83	17.80	83.31	6.72

Table III contains the analytical figures of irrigated indigenous canes.

All of these canes are poor in sucrose and have a very low purity, as will be evident from a comparison of the two preceeding tables.

TABLE IV.

Analyses of unirrigated canes.

Variety of cane.	November 1925.				December 1925.				January 1926.				February 1926.			
	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %	Sucrose in juice %	Brix	Purity	Sucrose in bagasse %
S. 48	17.71	20.00	88.55	6.51	18.92	21.50	88.00	6.48	19.31	22.01	87.73	7.82	18.50	21.30	86.85	7.75
Co. 214	16.20	19.50	83.08	6.80	17.61	20.50	85.90	6.92	17.21	20.40	84.36	7.93	16.13	19.80	81.46	7.71
Co. 221	16.42	18.80	87.34	6.22	17.82	20.40	87.35	6.41	Not determined			Not determined		Not determined		
Yuba	12.12	15.60	77.69	6.12	14.71	17.50	84.06	6.92	14.35	17.50	82.00	7.10	13.51	17.00	79.41	6.83
Ledu	11.11	14.80	75.06	6.28	13.46	16.00	84.13	6.38	13.16	16.00	82.25	6.41	12.81	15.90	80.56	6.20

The above table shows the monthly variations in the sucrose contents of unirrigated canes. Most of these canes had a higher percentage of sucrose than was found in irrigated canes, but they invariably gave a very low acreage outturn. Consequently the yield of the sucrose per acre from unirrigated canes was much lower than that obtained from irrigated canes.

TABLE V.

Average Analytical data for the season 1925-26.

Variety of cane.	Sucrose in cane. %	Sucrose in juice. %	Brix.	Purity.	Remarks.
S. 48	13.96	17.90	20.49	87.36	
Co. 213	13.15	16.58	19.12	86.52	
Co. 214	12.85	16.04	18.88	85.06	
Co. 221	13.68	17.35	20.06	86.50	
Lakhapur (P.O.J. 33)	14.58	16.94	19.59	86.50	
Manjav	14.86	17.61	20.15	87.39	
Nasik Khadia	9.71	10.34	14.46	71.70	
	Irrigated Indigenous Canes.				
Yuba	10.59	12.25	16.57	73.80	
Dhaul	10.12	12.15	16.04	75.55	
Munhtora	10.87	13.09	16.65	78.41	
	Unirrigated Canes.				
S. 48	14.18	18.61	21.20	87.77	
Co. 214	13.04	16.84	20.05	83.64	
Co. 221	13.00	17.12	19.60	87.35	
Yuba	11.10	13.67	16.90	80.89	
Ledu	10.29	12.62	15.48	81.47	

The above table gives the sucrose contents of exotic, seedling, indigenous and unirrigated canes confirming the previous discussion.

TABLE VI.

Analyses of rab.

Serial No.	Variety.	Sucrose in **rab** %	Brix.	Purity.	Remarks.
1.	S. 48	81.68	94.57	86.36	
2.	P.O.J. 33	76.21	93.46	81.54	
3.	Co. 221	73.12	90.85	80.48	
4.	Co. 214	71.86	89.85	79.97	

TABLE VII.

Analyses of gur.

Serial No.	Variety.	Sucrose in **gur** %	Remarks.
1.	S. 48	83.91	
2.	Co. 214	78.89	
3.	Co. 221	79.12	
4.	P. O. J. 33 (**Lakhapur**)	79.21	
5.	**Yuba**	73.12	

TABLE VIII.

Polarisation :—

First Sugar ...	... ..	97.50*
Second sugar	... ..	94.0*
Qand (refined sugar)	...	99.2
Bura from second sugar	..	89.0
Final Molasses	.. ...	35.02

In tables VI and VII are given the sucrose contents of **rab** and **gur** respectively of several varieties of canes grown on field scale.

The factors which govern the percentage of sucrose in the above two kinds of raw sugars (**rab** and **gur**) have been fully discussed in the writer's Chemical note for 1926-27 and the reader is referred to it for more detailed information.

* With more recent improvements in the processes of manufacture the polarisation of both kinds of sugar has risen much higher.

CHEMICAL NOTE,

by

K. Dubey, M.Sc., M.A.C.S., F.S.T.A. etc.

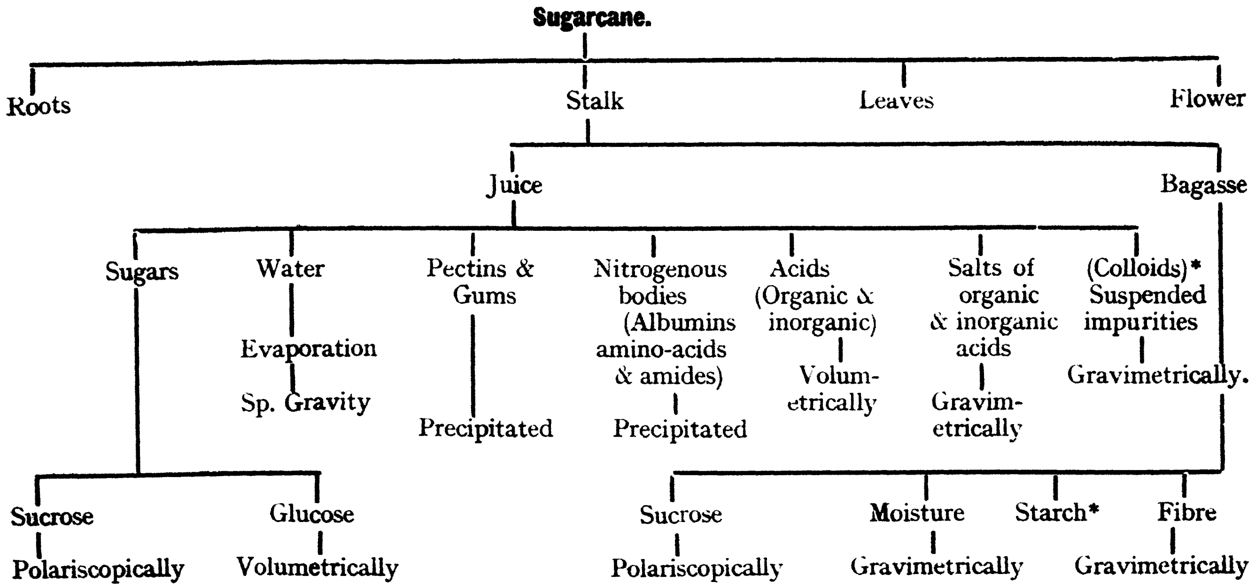
C. Research Season 1926–27.

Constituents of Sugarcane. Physically sugarcane consists of roots, stalk, leaves and flower, where it is liable to flowering. It is however the stalk of the plant which has held the attention of investigators from time immemorial and in the following pages the writer proposes to discuss briefly the important constituents of the cane-stalk and their ultimate bearing on the final recovery of crystallisable sugar from the juice obtained from cane-stalk.

In the majority of cases the cane-stalk has a coating of wax on the outside and is impregnated with varying shades of colours from almost white to pale-yellow, from light-red to dark-red, from light-green to dark-green and from light-purple to dark-purple. The pithy part of the stalk consists of cellulose technically called "fibre." Inside the cells of the fibre is stored plant sap containing sucrose or crystallisable sugar, glucose or so-called uncrystallisable sugar, suspended and dissolved impurities, tannins, albumins, gums, colloids, organic and inorganic acids and salts of these acids, every one of which has a special function to perform in the growth and development of the plant and in the synthesis of sugar in the stalk. The proportion in which these constituents occur varies in different varieties, in different stages of season, in different climatic conditions and is influenced by disease and attack of pests.

The following diagram illustrates briefly the composition of sugarcane, sugarcane stalk and sugarcane juice and the methods by which these constituents are determined in chemical laboratories.

CHART 1.



* Not determined usually.

The chief function of roots is to supply nutrients to the plant during the period of its growth while the synthesis of sugars takes place through the medium of the leaves, whence they are transported to the cane stalk, part of the uncrystallisable sugar being used by the plant for respiration and the rest remaining in the juice. In the early stages of growth sucrose becomes inverted and is used partly for respiration and partly for the formation of starch, but as the season advances and the leaf-bearing joints begin to mature, sucrose is no longer inverted into glucose, but begins to accumulate in the maturing joints, while part of the reducing sugars is transferred upwards to younger and less mature joints. When this stage is reached the leaf attached to the joint withers and falls off. The function of the flower is to show that the cane, when it flowers, has reached a stage at which its physical growth is stopped and the point of maturity has almost arrived. Cane flowers also serve the purpose of reproduction.

Effects of the constituents of sugarcane juice on the final recovery of crystallisable sugar.

(1) Other things remaining the same the higher the percentage of sucrose in the juice the higher will be the final recovery.

(2) The lower the percentage of reducing sugars* in the juice and the boiled mass, the higher will be the recovery of sugar in the centrifugal machine, as the large amount of reducing sugars not only lowers the yield of sucrose but also helps its further inversion into reducing sugars in the course of boiling.

(3) Pectins and gums are only partly precipitated by small amounts of alkalies used in defecation but can be wholly precipitated by liberally using sodium bi-carbonate. If they are left in the juice the final product, after the boiling is over, will be viscous and liberal washing with hot water will be required to cure the sugar completely in the centrifugal machine, thereby entailing loss on the recovery of sucrose.

(4) Nitrogenous bodies which are present in cane juice must be thoroughly removed in the course of defecation as they will produce a dirty looking **rab,** which on curing will contain an appreciable quantity of foreign matter and will not suit cultured taste.

(5) Organic and inorganic acids are present in small quantities in fresh mill juices in the case of unripe and fully ripe canes, but in larger quantities in over-ripe canes. If the quantity of these acids is rather large in fresh mill juice then the cane is overripe or has been damaged in some way; the neutralisation of these acids will be essential in the course of defecation, otherwise during the concentration of juice the presence of these acids will hasten inversion of sucrose and consequently a low yield of sugar from such a **rab** when cured will be obtained.

* The glucose, the fructose and the mixture of both these sugars is commonly known as "reducing sugars" because they have the property of reducing an alkaline solution of cupric oxide to cuprous oxide.

(6) Salts of organic and inorganic acids are present in such small quantities that they have little or no effect on the final yield of sugar from cane.

(7) In chemistry the colouring matters are divided into two primary groups, namely, pigments and chromogens. Pigments occur already formed in plants and chromogens derive their colour from these pigments during the process of boiling and defecation. The colouring matters which usually occur in the cane are Chlorophyl, Anthocyan, Polyphenols and Saccharetin.

Chlorophyl is insoluble in water and is removed by filtration and in defecation. Anthocyan is soluble in water and generally occurs in the juice of dark coloured canes. It can be precipitated by alkalies and is thus removed during defecation. Saccharetin, the yellow colouring matter of cane fibre, is the only persistent colour which is difficult to remove. This pigment is however colourless in acid solutions and sodium-hydrosulphite solution, which has an acid reaction, may be used advantageously in washing the sugars, in the centrifugal machine, obtained by open-pan system of boiling from yellow coloured canes.

The colouring bodies which are formed during the process of boiling are the decomposition products of reducing sugars, coloured iron compounds and coloured products due to over-heating, e.g., caramel, etc.

The coloured compounds of reducing sugars are only partly bleached by sulphurous acid and chlorine compounds and even this decolourisation, as with all reducing agents, is only temporary. Since glucose as such is colourless and only breaks up into salts of organic acids in an alkaline solution, every effort should be made to keep the boiling juice slightly acid so as to prevent the glucose being attacked, but the degree of acidity must not be allowed to rise, as inversion will take place quickly and there will be a loss of crystallisable sugar. No work has so far been done on solving this problem in the open-pan system of boiling, but it is intended to make a study of this problem next season and the results of the investigation will be placed before the reading public in the near future. The coloured salts of iron are formed from the material carried from mills, tanks, containers and pans, while the coloured products of over-heating are formed when the juice in the pans is allowed to become overheated and the sugar partly converted into a brown material called caramel.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{overheated}} C_{12}H_{20}O_{10} + 2H_2O$$

Sucrose + Water → Caramel + Water (a coloured compound)

It is impossible to bleach the caramel and products of glucose decomposition formed in the course of boiling. Sugar manufacturers will therefore be well advised to keep all the pans full to the utmost practicable capacity and to strike the finishing pan with care and dexterity, as it is in this pan that much of the caramel is formed.

To sum up. The higher the percentage of sucrose in the juice, the higher will be the final recovery of sugar and the lower the percentage of glucose, tannins, colloidal matters, albumins, gums, and other impurities in the clarified juice, the higher will be the final recovery of sugar obtained from the **rab** boiled from such a juice. Finally the smaller the amount of colouring matters in the juice either present in cane or developed in the process of boiling, the better will be the quality of sugar obtained from it and the higher will be the yield of sugar on cane.

During our investigations, on the possibilities of sugar production in Malwa, it was found desirable to determine how the sugar moved upward from the bottom of the cane towards the top during the period of ripening For this purpose the cane was divided in the first instance into two parts namely (1) the "white top" used for feeding cattle in Malwa and for planting in Rohelkhand and (2) the part ordinarily used for crushing. This latter part was again for purposes of chemical examination divided into 3 equal parts, viz.,

(1) Bottom portion

(2) Middle ,,

(3) Top ,,

The results of this investigation, which are tabulated below, prove that as early as November the bottom part of the stalk contained the highest percentage of sugar which moved upward as the season advanced. In the month of March the highest percentage was found to be contained in the top part, and the ratio of sugar between the upper and the lower parts which had reached unity in February was reversed in favour of the top part in March.

TABLE I.

Movement of sugars in cane during the period of maturity.

Variety of cane.	Field No.	Date of Analysis	Constituents determined	Bottom	Middle	Top	White tops.	Middle/Bottom Ratio	Top/Bottom Ratio	Top/Middle Ratio
S. 48 Plant crop	23	20–11–26	Brix	18.5	16.8	14.5	..	0.9	0.78	0.86
			Sucrose %	15.98	15.27	10.8	3.1	0.95	0.67	0.70
			Purity	86.38	77.91	74.48	..	0.90	0.86	0.95
			R. S. %	0.65	1.07	1.35	2.2	1.66	2.08	1.26
,,	,,	19–12–26	Brix	18.9	18.5	15.00	..	0.98	0.79	0.81
			Sucrose %	16.45	15.65	11.32	3.2	0.95	0.68	0.72
			Purity	87.03	84.59	75.46	..	0.97	0.86	0.89
			R. S. %	0.56	0.92	1.01	2.05	1.64	1.80	1.09
,,	,,	18–1–27	Brix	19.5	18.9	17.5	..	0.96	0.89	0.92
			Sucrose %	16.41	16.45	14.14	5.2	1.00	0.87	0.87
			Purity	84.15	87.03	82.03	..	1.03	0.97	0.93
			R. S. %	0.56	0.65	0.89	1.7	1.16	1.58	1.37
,,	,,	20–2–27	Brix	21.5	21.4	21.2	..	0.99	0.98	0.99
			Sucrose %	18.38	18.91	18.38	7.2	1.02	1.00	0.98
			Purity	85.8	88.36	88.39	..	1.03	1.03	1.00
			R. S. %	0.50	0.50	0.42	1.2	1.00	0.84	0.84
,,	,,	13–3–27	Brix	21.7	22.0	21.8	..	1.01	1.00	0.99
			Sucrose %	17.8	19.4	19.66	8.8	1.08	1.10	1.01
			Purity	82.02	88.18	90.18	..	1.08	1.11	1.02
			R. S. %	0.92	0.37	0.37	0.92	0.40	0.40	1.00

Note.—R. S. denotes reducing sugars.

CHARTS II & III.

Chart II illustrates graphically the movement of sucrose in cane and shows that the lowest percentage of sucrose contained in the top part early in November kept on increasing, till in March this part of the cane had the highest percentage of sucrose. The bottom part of the cane which attained the highest percentage of sucrose in February deteriorated rapidly in March. The middle section of the cane which kept on gaining in sugar also showed a slight deterioration in March.

Chart III illustrates the rise in purity of various parts of the cane and shows that the bottom part of the cane which had attained highest maturity in December began to show a fall until in March its purity came down from 87.03 to 82.02, though the bottom part never attained the purity of 90° of which the cane seems to be capable. The middle section of the cane showed a slow rise in purity, reaching its maximum in February, and then showing a slight fall in March. The top section which had a purity of only 77.91 in November attained a maximum of 90.18 in March, the highest which the cane seems to be capable of attaining.

It is thus apparent that S. 48 which was used in this experiment and which was planted early in January was over-ripe in March, though the normal distribution of sucrose in the cane was still faintly visible. The loss of sucrose in the bottom part of the cane can not however be compensated by gain in the top part, as the bottom part of the cane is much thicker and heavier than the top part and consequently contains more sucrose than the top part. It must, however, be remembered that the period of maturity of sugarcane varies with different varieties, with the time of planting and with meteorological and soil conditions. What the attached table and charts clearly illustrate is the fact of upward movement of sucrose in cane and the deterioration of its bottom part which will be true of all canes when analysed under similar conditions during the ripening period. The white-tops which were also analysed contained comparatively a small percentage of sucrose throughout the season and a rather high percentage of reducing sugars.

In practical sugar manufacture this will mean that if the crushing is to be started early in December, then as much as half of the cane from the top downwards may be used for planting and the remaining half crushed, the juice being boiled into **gur** or **rab.** In business economics this means that the rich juice obtained from the lower half would be boiled with less expenditure than required for boiling the juice containing a high percentage of reducing sugars and water, were the whole cane to be crushed; because the juice of the upper half of the cane which contains less

sucrose will dilute the whole amount to convert which into **rab** or **gur** more fuel and more time would be required. If the white-tops were also crushed then a still higher percentage of reducing sugars will be introduced (table I) the presence of which not only produces a final product of inferior quality but also favours further inversion in course of the boiling. We would therefore suggest that white-tops should always be removed from the cane, which is to be crushed, and used for planting purposes.

The presence of high percentage of reducing sugars in this part of the cane gives a better and healthier germination than that obtained from the whole cane and the final crop at the end of the season gives as good an acreage outturn as is obtained by planting the whole cane. A comparison of the analyses of the crops grown from tops and whole canes respectively showed that there was no deterioration in the sucrose content of the juice of the former crop. On the contrary, there was an appreciable increase of sucrose in the juice from one of the fields containing the crop grown from tops.

TABLE II.

Showing the variations in sucrose, etc. of Cane S. 48 grown from tops and whole canes.

Crop grown	Farm	Field	Brix	Sucrose %	Purity	Reducing sugars %
From Tops	Nuzhat Afza,	26	18.78	16.32	86.9	0.92
From whole cane	,,	26	18.78	16.32	86.9	0.92
From Tops	,,	31	20.68	18.24	88.2	0.69

Care must however be taken never to plant the tops of infected canes as they are liable to produce disappointing results, owing to the germs being most active in this vital part of the plant.

If the cane is planted late, say in March, Chilo Simplex, the deadly enemy of this valuable crop plays havoc with it during the hot summer months of May and June if not earlier and the new shoots which sprout in the rainy season are not advanced enough in age to mature at the time when crushing is generally started in Malwa. The results of the analyses of Co. 221 which was planted

late and was also attacked by Chilo Simplex are given below.

TABLE III.

Showing the effect of Chilo Simplex on the constituents of cane.

Farm Nuzhat Afza	Field	Healthy or affected	Date of Analysis	Brix	Sucrose %	Purity	Reducing sugars %
"	13	Healthy	9-1-27	19.9	18.02	90.55	0.69
"	"	Affected	17-1-27	19.42	14.78	76.10	1.85
"	"	Healthy	4-2-27	20.97	18.94	90.32	0.43
"	"	Affected	9-2-27	20.98	17.29	82.41	0.96

A comparison between the above results and those given for the analyses of normal and healthy crops of Co. 221 proves that the juice of normal cane, when analysed about a week earlier than the juice of the cane attacked by Chilo, contained 3.24% more sugar, had 90.55 purity and contained only 0.69% of reducing sugars. Though this difference became less and less as the season advanced, yet even in the early part of February the difference in sucrose of the two crops was 1.65, in purity about 7.9 and 0.53 in reducing sugars. Thus the analyses of these canes show that the crop attacked by Chilo was still unripe and the crushing should have been postponed if maximum returns were to be obtained from it, but this would have involved an extra expenditure on irrigation and under manufacturing conditions every anna saved means an addition to the manufacturer's profits.

To save himself from a loss of this kind, the planter-manufacturer is advised to start early planting and give the plant stalk sufficient time to become hard enough and impermeable to the attack of the borer by the time it makes its appearance, which is generally in May and June.

Planting of cane should be started late in December if the weather is not too cold, but it should certainly be started in January whatever the weather conditions. The part of the cane which is recommended for planting purposes at this time of the season is the upper half including white tops, as it contains less sucrose and comparatively more glucose than the bottom or the middle part of the cane and is practically unfit for crushing, which is proved by reference to table I.

If such a practice is adopted the manufacturer will doubtless have a double advantage, viz: a high percentage of sucrose recovery from the cane and a better crop next year.

Colletotrichum falcatum (Red Rot).

This disease, which may be regarded the plague of sugarcane, was suspected in **Lakhapur** (P.O.J. 33) and the local **Paunda.** The analyses of canes affected by it show that the purity of those canes became stationary during the period the signs of the disease became manifest, and though a slight rise was noticed towards the end of the season, it was very small compared with the rise of purity in the canes which were healthy, the percentage of sucrose being very low, whereas that of reducing sugars was very high.

TABLE IV.

Showing the effects of attack of the Red Rot on the constituents of sugarcane.

Farm Nuzhat Afza.	Field.	Variety.	Date of Analysis.	Brix.	Sucrose %	Purity.	Reducing sugars %	Remarks.
..	9	**Lakhapur** (P.O.J. 33)	22-11-26	16.00	12.40	77.50	1.58	Infected by Red Rot.
..	,,	,,	8-1-27	17.48	13.13	75.11	1.26	,,
,,	,,	,,	23-1-27	17.49	13.86	79.24	0.89	,,
,,	,,	,,	24-1-27	19.97	17.48	87.53	0.73	Selected from healthy canes.
,,	,,	,,	9-2-27	21.24	18.91	89.03	0.58	,,

A comparison between affected and healthy canes analysed on 23rd and 24th January shows a difference of 3.62% sucrose, 8° purity and 0.16% reducing sugars.

A few cartloads of local **Paunda,** badly infected by Red Rot, were received from one of the neighbouring farms, the juice of which contained only 11.86% sucrose. When crushed immediately on arrival at the Research Station it produced **gur** of a fairly good quality, but owing to its arrival late in the afternoon part of the cane had to be kept overnight, with the result that when it was crushed next morning and the juice boiled into **gur** the final product failed to solidify.

From the above facts it is perfectly clear that if the cane is attacked by Red Rot, the best thing to do is to harvest it as soon as possible, but the most important thing is to crush it immediately after harvesting. If this precaution is not taken, then all that the manufacturer will finally get after a good deal of trouble and expenditure will be a sort of black, sticky, semi-liquid mass unfit for human consumption.

Effect of over-manuring.

In a section of Field no. 26 an excessive amount of ammonium sulphate had been given inadvertently and this became known later on. The effect of this mistake was a very good germination and a vigorous vegetative growth in the early part of the year, but the cane began to lodge freely during the rainy season and had to be tied to strong bamboo poles to keep it standing. Even after this precaution there was some lodging, as will be evident from the comparison between table X page 260 and the analysis given below. In this analysis only standing canes were used as the fallen canes are dealt with separately.

TABLE V.

Showing the effect of over-manuring

Variety. of cane.	Date of Analysis.	Farm Nuzhat Afza	Field No.	Composition of juice				Composition of Bagasse		Composition of cane		
				Brix	Sucrose %	Purity	Reducing sugars %	Sucrose. %	Fibre %	Sucrose %	Reducing sugars %	Fibre. %
S.48	29-11-26	,,	26	17.70	13.12	74.10	1.18	5.93	38.8	11.16	0.79	12.81
,,	8-1-27	,,	,,	17.67	13.87	78.49	0.76	6.90	44.57	11.43	0.49	14.61
,,	24-1-27	,,	,,	18.45	16.04	86.94	0.79	5.53	49.80	12.73	0.54	15.73
,,	17-2-27	,,	,,	21.14	18.96	89.68	1.00	6.56	40.95	14.84	0.65	15.63
,,	24-3-27	,,	,,	21.50	19.51	90.74	0.37	6.65	48.00	15.99	0.25	16.48

Lodging. Lodging is always due to one or more of the following causes :—

(1) Over-manuring which results in a vigorous vegetative growth. Lodging is always more frequent in heavily manured plots. (2) Wind and rain storms which bend the tender cane stalk and blow it down eventually. (3) Climatic and moisture conditions. If during the earlier period of its growth the cane is not well supplied with moisture it is liable to develop a spindling stalk and if at a later period the moisture conditions improve the canes develop a heavy top growth and the tendency to lodge is greatly increased. (4) Inadequate earthing up and shallow planting. If the cane is inadequately earthed up its bottom part is unable to support the weight of the whole stalk, the cane bends and eventually falls down. Similarly if the planting is shallow there is excessive tillering and the main roots become weak, producing thereby a lodging tendency in such a crop. (5) Inherent tendency of certain canes to lodge. (6) Excessive watering which results in heavy growth.

The lodging of sugarcane in the field, however, has other consequences than the extra difficulties in cutting, handling and milling the badly fallen canes. When the stalk of the cane falls or is blown down, its growth is checked and the quality of the juice suffers appreciably as will be evident from the attached table.

TABLE VI.

Showing the effect of lodging on the constituents of sugarcane.

Variety.	Plant crop or Ratoon.	Farm Nuzhat Afza	Field No.	Fallen or Standing	Date of Analysis	Brix.	Sucrose %	Purity.	Reducing sugars %
Co. 221	Ist. Ratoon.	,,	20	Standing.	10-1-27	20.57	17.81	86.58	0.58
,,	,,	,,	,,	Fallen.	10-1-27	18.15	14.92	82.20	1.79
S. 48	Plant Crop.	,,	26	Standing.	17-2-27	21.14	18.96	89.68	1.00
,,	,,	,,	,,	Fallen.	17-2-27	19.34	16.78	86.78	1.74

The results of the above analyses show that the juice of fallen Co. 221, First Ratoon, contained 2.89% less sugar than the juice of the standing cane taken from the same field and analysed on the same date. Similarly the juice of the fallen S. 48 plant crop contained 2.18% less sucrose, had 2.9° lower purity and contained 0.74% more reducing sugars. From the Brix readings of the fallen and standing canes it appears that the juice of fallen canes was more dilute than that of standing ones. This may, in the writer's opinion, mean that the cane was still unripe and would have required to be left in the field longer than the standing canes, which of course would be impracticable under manufacturing conditions, as the expenditure involved in irrigating those patches of the field in which lodged canes still remained unharvested would be very heavy indeed. The writer has calculated elsewhere the loss of available sugar on cane juice, when the cane is injured in one way or the other, and would refer the reader to that illustration to compare the loss of available sugar in fallen canes with that of standing canes.

It will doubtless pay in the long run if the precautions enumerated below are taken by planters the moment their crop shows a tendency towards lodging :—

(1) Judicious manuring of fields specially if the soil is rich and strong.

(2) Planting of sets fairly deep and widely apart.

(3) Adequate earthing up.

(4) Tying up the stalks in opposite rows when the cane has grown fairly tall.

(5) The selection of a variety little disposed to lodging.

(6) Abstinence from excessive watering, especially, if the cane is grown in rich Malwa soils.

Effect of Frost on Sugarcane Crop.

In the first week of January 1927 there was a severe frost of short duration and the sucrose percentage in some of the canes analysed afterwards was appreciably lowered, the percentage of reducing sugars rose to a perceptible figure.

TABLE VII.

Showing the effect of frost on the constituents of sugarcane.

Variety.	Farm Nuzhat Afza	Field No.	Date of Analysis.	Before or after frost.	Composition of juice.			
					Brix.	Sucrose %	Purity.	Reducing sugars %
S.48	,,	26	29–11–26	Before	17.67	13.87	78.49	0.76
,,	,,	,,	8–1–27	After	17.70	13.12	74.12	1.18
Manjav	,,	15	28–12–26	Before	17.89	15.40	86.09	1.23
,,	,,	,,	9–1–27	After	18.73	15.43	83.23	1.79
Co. 213	,,	23	24–12–26	Before	19.84	16.01	80.69	1.08
,,	,,	,,	10–1–27	After	20.91	17.61	84.22	0.92

The fall in sucrose content of S. 48 is appreciable while the deterioration of Manjav is proved by a fall in purity which decreased from 86.69 to 83.23. In both cases there was also a noticeable rise in the percentage of reducing sugars, Co. 213 seems, however, to have resisted the frost very well, proving thereby that some canes are more susceptible to damage than others.

Deterioration of cut canes.

The following determinations were made to find out the loss in sugar when ripe and harvested canes are stored for 24 hours, under varying conditions of temperature.

TABLE VIII.

Showing the deterioration of cut canes.

Variety of cane.	Treatment.	Time of the year	Composition of juice.				Available sugar on the basis of the Brix of fresh canes.
			Brix.	Sucrose. %	Purity.	Reducing sugars %	
S.48	Crushed fresh.	Febry. 1927	20.2	17.49	86.58	0.75	17.49
,,	Stored indoors for 24 hours.	,,	20.3	17.25	84.97	0.78	17.17
,,	Stored in the sun for 24 hours.	,,	20.5	17.14	83.61	0.81	16.89
Co. 221	Crushed fresh.	,,	20.5	17.93	87.46	0.79	17.93
,,	Stored indoors for 24 hours.	,,	20.65	17.71	85.76	0.82	17.58
,,	Stored in the sun for 24 hours.	,,	20.8	17.58	84.52	0.92	17.33

Calculating the figures for sucrose on the basis of the Brix of fresh canes we find the loss of available sugar in the juice of S. 48 and Co. 221 to be 0.32% and 0.35% respectively for canes stored in shade and 0.6% for canes stored in the sun. This means that on 100 maunds of original available sugar (in S. 48 and Co. 221) 1.82 maunds and 1.95 maunds respectively of sugar were lost on the canes stored in shade and 3.43 maunds and 3.35 maunds respectively on canes stored in the sun. These losses will be further enhanced owing to the higher percentage of reducing sugars in the juice of stale canes.

Loss of sugar in stale juice.

In open-pan systems of boiling the juice is generally left in **Mattas** and pans for 4 to 5 hours, usually at 25°C to 30°C, with the result that the inversion and fermentation go on continuously and there is a great loss of sugar on that account. An experiment was carried out with the juice of **Lakhapur** (P.O.J. 33) to actually determine this loss, the result of which is tabulated below. The juice was analysed as it came from the mill, then kept for 5 hours at 28°C and analysed again.

TABLE IX.

Showing the deterioration in stale juice.

Variety of cane.	Fresh juice or stale.	Composition of juice.				Available sugar on the basis of the Brix of fresh juice.
		Brix.	Sucrose. %	Purity.	Reducing sugars %	
Lakhapur (P.O.J.33)	Fresh juice	21.24	18.92	89.07	0.58	18.92
,,	Juice left for 5 hours at 28°C.	26.20	20.42	77.94	0.69	16.55

It is apparent from the above figures that 2.37% available sugar was lost in the juice when allowed to stand for 5 hours at 28°C or 12.53 parts on 100 parts of available sugar. This loss will be still greater if the temperature were higher than 28°C. When calculated in terms of rupees the loss on 100 maunds of available sugar @ Rs. 12 per standard maund comes to Rs. 150-5-9. Assuming that only 60% of this available sugar could be recovered then the actual loss calculates to about Rs. 90 on every 100 maunds of available sugar. This loss would calculate to a very staggering figure indeed for the whole season of 100 to 120 days. Nor do the figures given above represent the real loss which takes place where the juice is left in earthen vessels which are not washed regularly during the whole season and which consequently harbour millions of bacteria. These parasites start their function immediately after they come in contact with the juice and go on doing so until they are killed by the higher temperature of the boiling pans.

At the Research Station earthen vessels are not used but kerosene tins which are washed every day. Then again the juice was left in the writer's laboratory under most sanitary conditions. Consequently the above figures represent a loss which would take place under conditions not favourable for bacterial growth. This loss would be further enhanced if the temperature were higher than 28°C, the optimum being 60°C. The writer would therefore suggest that it is in the interest of manufacturers not to keep any juice stored up but to send it right away to the boiling pans, where it should be quickly heated to boiling temperature and then may be left standing if necessary.

Role of Fibre in cane.

The chief function of cane fibre, as has been said before, is to protect the very life of the plant. It is through the fibre cells that the sap moves up and down and supplies the nourishment to other organs of the plant. The fibre content of a cane rises as it grows in age; and varies with different varieties. Medium and thin canes have a much higher percentage of fibre than thick, soft and juicy canes as will be evident from table XIV. In the case of the former the fibre cells are more closely packed together and the canes are for that reason hard and tough and also give a lower extraction of juice. In thick canes the fibre particles are loosely held together and consequently a higher extraction is obtained from them, when the same pressure is applied as in the case of medium canes. But it is also true that the fibre of every variety of cane has its own power to resist pressure. For the same reason thick canes are easily damaged by wild animals and are more susceptible to disease.

Before commenting on the data contained in tables X, XI, XII, XIII, and XIV the writer would like to say that in his research work he has been greatly handicapped for want of a bagasse

chopping machine. The samples of bagasse as they came from the mills contained varying amounts of juice and consequently the percentage of fibre and sucrose varied according to the amount of moisture and sugar contained in the bagasse. This difficulty was further aggravated by the fact that the bagasse sample for analysis had to be chopped with a carpenter's chisel, causing an inevitable loss of moisture by simple evaporation; which varied with the temperature and the time taken in chopping the sample.

The results of fibre and sucrose in bagasse therefore represent more or less approximate determinations possible under the existing conditions. As this publication is meant both for scientists and manufacturers with a special emphasis for the enlightenment of the latter the work had to be done under the conditions actually prevalent on a sugar estate which has essentially caused some slight variations in the results. It may however be safely said that the results contained in the tables to be discussed shortly throw a flood of light which should be of interest equally to scientists and manufacturers.

Table X pages 259 to 264 shows that the constituents of the same variety of cane not only varied from field to field but even in different parts of the same field and that the constituents of different varieties are different. The last statement is clearly proved by tables XIII and XIV. Pages 267 to 268 and 269 respectively.

In table XI page 265 are given the analyses of canes recently imported and grown in the nursery. Some of these canes, viz. B. 208, Ashy Mauritius, Co. 210, Waxy Red, etc., showed all round good qualities and give a future promise of being suitable to Malwa conditions.

In table XII page 266 are given the analyses of indigenous canes which have given low acreage outturn and are very poor in sucrose and have consequently been discarded.

Table XIII page 268 shows the approximate monthly variations in the constituents of different varieties and gives an idea as to which of the varieties could be crushed in November, December, January, February or March.

This fact is of great importance to the manufacturer whose working season is usually limited to a 100 to 120 days. If he could obtain mature canes throughout this period he would be able to extract maximum sucrose out of the cane crushed. He would never be able to do this unless he were to grow more than one variety some of which may mature early and some late.

Chart IV shows that Co. 214 was mature in November, then its sucrose came down suddenly and remained practically constant.

Co. 221 which is the next cane to show a high percentage of sucrose in November matured in January and then began to deteriorate in the latter part of February and the beginning of March.

S. 48 is the third variety which contained a comparatively high percentage of sucrose in November and was ready for crushing in February.

Manjav and **Lakhapur** (P.O.J.33) were not in their normal condition, the manure having been washed out of the field No. 15 in which the former was grown and the latter having been attacked by Red Rot. Where these canes did not have any of the above disadvantages they showed high sucrose and good purity (table X field 23.)

Co. 213 which contained least sucrose in November showed a rapid gain in December, January, February and March, till it was finally dealt with early in March.

Thus we find that a manufacturer, to obtain the best results, would be well advised to grow Co. 214, a poor yielder of acreage outturn, if he wishes to start early crushing, and also Co. 213 if he wishes to continue working till the end of March, together with other varieties which mature during the interval.

In table XIV Page 269 are given the constituents of canes grown on field scale.

Among medium canes S. 48 contained the highest percentage of sucrose, Co. 221 stood second, Co. 214 third and Co. 213 fourth. Co. 221 had highest purity, S.48 came next, Co. 213 came third and Co. 214 was last. Co. 214 contained the highest fibre and Co. 221 the lowest. Of thick canes **Lakhapur** (P.O.J. 33) had highest sugar and lowest fibre, while **Manjav** had highest purity.

Of all the canes Co. 221 and S.48 contained the least percentage of reducing sugars and **Manjav** the most.

Loss of recoverable sugar on account of inefficient mills.

It is apparent from the figures contained in table XV Page 270 that a great loss of recoverable sugar (from cane) takes place owing to the use of mills which give an average extraction of 61% juice from thin canes, 66% from medium canes and 73% from soft and thick canes.

The average loss of sucrose in milling comes to 7.23% on 100 of extractable sugar on all six varieties given in the above table.

If the mills were really efficient and if 89.5% of recoverable sugar could be extracted from canes containing an average of 13.96% then the recovery of sugar lost on account of defective milling would come to 0.74% and the final recovery would be about 9 p.c. on cane, the actual figures being 9.05 instead of 8.32 as at present. This problem assumes serious proportions when it is remembered that a working season consists of 100 to 120 days and that several tons of cane are crushed every day even in a factory of moderate size. Indeed the salvation and future prosperity of the indigenous sugar industry lies as much if not more in the introduction of efficient milling plants as in the growing of canes containing a high percentage of sucrose.

TABLE X.

Analysis of Plant Crops of cane varieties grown on field scale.

Variety of cane.	Date of analysis	Farm & field No.	Composition of juice				Composition of Bagasse		Composition of cane.			Remarks.
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre* %	Sucrose %	Reducing Sugars %	Fibre* %	
S.48	24-11-26	N. Afza	19.00	15.60	82.10	0.87	.38	49.50	12.56	0.57	16.33	
,,	26-12-26	23	19.50	16.68	85.54	0.69	6.41	47.20	12.92	0.46	15.77	
,,	17-3-27	,,	22.48	19.88	88.43	0.63	6.58	44.35	15.99	0.41	15.21	
,,	2-12-26	,,	20.48	17.92	87.50	0.85	7.40	48.50	14.77	0.57	16.42	Unirrigated.
,,	6-1-27	,,	22.24	19.59	88.08	0.85	7.40	52.52	15.82	0.57	17.33	,,
,,	20-2-27	,,	23.23	21.91	94.79	0.65	8.65	50.21	17.27	0.42	16.57	
,,	2-12-26	15	15.00	12.79	85.26	1.11	5.61	49.95	12.40	0.71	16.35	,,
,,	9-1-27	31	20.93	16.84	80.45	1.23	5.83	42.95	12.82	0.81	15.68	Grown from tops.
,,	16-1-27	,,	21.19	19.49	91.98	0.43	5.49	43.30	16.01	0.29	15.58	,, ,,

*Suitable apparatus was not available for bagasse analysis.

TABLE X.—Continued.

Analysis of Plant Crops of cane varieties grown on field scale.

Variety of cane.	Date of analysis	Farm & field No.	Composition of juice.				Composition of Bagasse		Composition of cane.			Remarks.
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre* %	Sucrose %	Reducing Sugars %	Fibre* %	
S.48	29-11-26	26	17.67	13.87	78.49	0.76	6.90	38.80	11.43	0.49	12.81	Fallen cane
,,	8-1-27	,,	17.70	13.12	74.10	1.18	5.93	44.57	11.16	0.79	14.61	
,,	20-1-27	,,	19.14	14.59	76.20	Not	deter-	mined	Not	deter	mined	
,,	24-1-27	,,	18.54	16.04	86.52	0.70	5.53	49.80	12.73	0.54	15.73	
,,	19-2-27	,,	19.34	16.78	86.78	1.74	6.61	44.00	13.34	1.15	15.83	Healthy canes
,,	13-2-27	,,	22.64	19.62	86.66	0.61	7.45	47.21	15.41	0.40	15.71	,, ,,
,,	17-2-27	,,	21.14	18.96	89.68	0.37	6.56	49.95	14.84	0.25	15.63	,, ,,
,,	24-3-27	,,	21.50	18.51	86.09	1.00	6.65	48.0	15.99	0.65	16.48	,, ,,

*Suitable apparatus was not available for bagasse analysis

TABLE X.—(Continued)

Analysis of Plant Crops of cane varieties grown on field scale.

Variety of cane	Date of analysis	Farm & field No.	Composition of juice				Composition of Bagasse		Composition of cane			Remarks
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre* %	Sucrose %	Reducing Sugars %	Fibre %	
Co. 213	23-11-26	N. Aiza 23	17.10	13.13	76.78	1.05	6.22	50.80	10.45	0.68	16.80	
,,	16-12-26	,,	17.27	13.62	78.86	1.06	6.09	48.02	10.92	0.93	17.28	
,,	24-12-26	,,	19.84	16.01	80.69	1.08	6.35	44.65	12.67	0.77	15.40	
,,	10-1-27	,,	20.99	17.61	83.89	0.92	6.37	48.18	13.82	0.62	15.02	
,,	21-1-27	,,	20.19	16.61	82.26	0.68	8.58	50.28	13.67	0.46	16.41	
,,	10-2-27	,,	22.74	19.74	86.80	0.64	6.11	50.25	15.17	0.40	16.57	
,,	3-3-27	,,	22.81	20.96	91.88	0.39	8.54	52.55	17.04	0.26	17.21	
Co. 214	31-10-26	13	18.20	15.01	83.42	1.44	6.12	46.85	13.21	0.94	16.39	
,,	29-10-26	,,	18.00	15.04	83.55	Not	determ	ined	Not	determi	ned	

*Suitable apparatus was not available for bagasse analysis.

TABLE X.—(Continued)

Analysis of Plant Crops of cane varieties grown on field scale.

Variety of cane	Date of analysis	Farm & Field No.	Composition of juice				Composition of Bagasse		Composition of cane.			Remarks.
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre* %	Sucrose %	Reducing Sugars	Fibre* %	
Co. 214	9-11-26	N. Afza 13	20.20	17.11	84.70	1.42	6.71	50.12	14.23	0.93	16.60	
,,	28-11-26	,,	22.51	18.87	83.82	1.38	6.89	50.15	14.67	0.90	16.61	
,,	11-12-26	22	21.68	18.55	85.56	0.79	5.93	50.21	14.78	0.51	16.72	
,,	25-1-27	23	21.97	17.51	79.70	0.88	7.85	47.65	14.19	0.58	16.57	
Co. 221	23-11-26	N. Afza	19.00	15.04	79.15	1.09	8.94	44.50	12.98	0.72	15.04	
,,	28-12-26	23	18.86	16.79	89.02	0.46	5.13	48.25	13.15	0.39	16.40	
,,	19-2-27	,,	21.81	19.09	87.53	0.74	6.12	46.15	14.62	0.48	15.91	
,,	2-3-27	,,	21.28	18.94	89.00	0.43	5.21	48.50	14.21	0.25	16.68	
,,	17-1-27	13	19.42	14.78	76.10	1.85	8.67	46.61	12.69	1.12	15.80	Attacked by Chilo Simplex

*Suitable apparatus was not available for bagasse analysis.

TABLE. X.—(Continued.)

Analysis of Plant Crops of cane varieties grown on field scale.

Variety of cane	Date of analysis	Farm & field No.	Composition of juice				Composition of Bagasse		Composition of cane			Remarks.
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre * %	Sucrose %	Reducing Sugars %	Fibre* %	
Co. 221	9-1-27	N. Afza 13	19.90	18.02	90.55	0.69	7.62	47.47	14.35	0.45	16.19	Healthy crop.
,,	4-2-27	,,	20.97	18.94	90.32	0.92	8.11	53.42	14.66	0.60	17.45	Healthy crop.
,,	9-2-27	,,	20.98	17.29	82.41	0.96	5.73	46.15	13.20	1.31	16.25	Attacked by Chilo Simplex
Manjav	22-11-26	15	15.02	11.97	79.67	1.22	8.98	37.90	11.06	0.95	10.43	
,,	28-12-26	,,	17.89	15.40	86.09	1.23	—	—	—	0.92	—	
,,	9-1-27	,,	18.73	15.43	82.38	1.79	10.5	38.90	13.96	1.25	12.11	
,,	21-2-27	,,	20.27	18.88	93.14	0.43	7.8	42.25	15.43	0.30	13.15	
,,	31-12-26	23	20.01	18.23	91.10	0.55	6.78	36.05	14.12	0.35	12.90	
,,	21-3-27	,,	20.87	19.10	91.57	0.37	7.18	39.55	15.74	0.26	11.86	

*Suitable apparatus was not available for the analysis of bagasse.

TABLE X.—(Concluded.)

Analysis of Plant Crops of cane varieties grown on field scale.

Variety of cane	Date of analysis	Farm & Field No.	Composition of juice				Composition of Bagasse		Composition of cane.			Remarks
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre* %	Sucrose %	Reducing Sugars %	Fibre* %	
P.O.J.	22-11-26	N. Afza 9	16.00	12.40	77.50	1.58	6.98	42.64	10.76	1.04	12.88	Healthy cane.
33	8-1-27	,,	17.48	13.13	75.11	1.26	—	—	—	0.88	—	
(Lakhapur)	20-1-27	,,	17.74	14.10	79.48	0.74	8.80	36.00	12.46	0.69	11.16	
,,	22-1-27	,,	19.97	15.72	78.72	1.00	8.02	36.00	12.51	0.69	11.13	Attacked by Red Rot
,,	23-1-27	,,	17.49	13.86	79.24	0.89	8.24	38.52	11.61	0.63	11.18	
,,	24-1-27	,,	19.97	17.48	87.53	0.73	8.05	37.25	14.69	0.51	11.02	
,,	9-2-27	12	21.24	18.92	89.07	0.58	9.29	34.25	16.03	0.41	10.27	
,,	26-12-26	23	18.76	16.58	88.37	0.79	8.16	39.35	13.96	0.44	12.19	Healthy cane.
,,	16-1-27	,,	19.29	17.43	90.35	0.56	9.01	40.11	14.93	0.39	12.00	Ditto.

*Suitable apparatus was not available for bagasse analysis.

TABLE. XI.

Analysis of Varieties grown in Nursery only.

Variety of cane	Date of Analysis	Farm & field No.	Juice analysis: Brix	Juice analysis: Sucrose %	Juice analysis: Purity	Juice analysis: Reducing Sugars %	Bagasse analysis: Sucrose %	Bagasse analysis: Fibre* %	Cane analysis: Sucrose %	Cane analysis: Reducing Sugars %	Cane analysis: Fibre* %	Remarks.
Red Mauritius.	24–11–26	Nuzhat Afza 23	17.41	13.42	77.08	1.46	8.76	44.74	11.99	1.01	13.78	
Striped Mauritius	12–1–27	Nabi Bagh 8/B	16.59	13.62	82.09	2.64	5.71	36.20	10.65	1.65	13.53	Reducing Sugars in this cane were usually high
,,	27–2–27	,,	19.67	17.25	87.69	1.01	5.47	39.85	14.74	0.68	12.95	
Ashy Mauritius	25–1–27	Nuzhat Afza 23	20.27	17.28	85.24	0.59	7.60	42.72	14.53	0.59	13.93	
,,	26–1–27	11	19.78	17.47	88.32	0.58	8.49	41.05	13.93	0.58	13.38	
B. 247	15–2–27	23	20.84	18.61	89.29	0.39	8.55	37.50	15.20	0.26	12.70	
B. 208	15–2–27	,,	20.64	19.35	93.75	0.48	8.58	32.45	16.00	0.33	10.11	
Waxy Red	28–11–26	,,	16.41	13.06	79.58	1.26	8.76	35.07	11.69	0.88	10.52	
,,	16–2–27	,,	21.41	19.43	90.75	0.91	6.65	37.05	15.48	0.63	11.48	
White Transparent	16–2–27	,,	20.14	17.26	85.70	1.28	6.28	40.35	13.66	0.86	13.24	
Co. 210	19–2–27	,,	20.81	19.59	94.13	0.68	8.09	42.25	15.81	0.45	15.41	

*Suitable apparatus was not available for bagasse analysis.

TABLE XII.

Analysis of Indigenous canes grown on field scale.

Variety of cane	Date of Analysis	Farm & field No.	Juice analysis				Bagasse analysis		Cane analysis			Remarks
			Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre* %	Sucrose %	Reducing Sugars %	Fibre* %	
Desi Paunda	23–10–26	H.H.'s Islamnagar Farm	14.80	11.36	76.75	1.76	7.80	......	Not dete	rmined..	......	
,,	30–12–26	,,	15.84	11.76	74.24	1.92	....	..Not	determin	ed......	......	
,,	24–10–26	N. Afza 23	13.50	9.87	73.11	1.75	....	..Not	determin	ed......	......	
,,	15–12–26	,,	16.69	13.73	82.26	1.38	7.89	42.20	11.98	0.97	12.66	
,,	5–1–27	,,	19.24	15.74	81.81	0.89	7.62	41.40	12.86	0.61	14.10	
Patta Patti	13–1–27	,,	17.88	12.83	71.76	1.35	5.25	45.72	10.92	0.89	15.54	
Hemja	13–1–27	,,	20.07	15.24	75.93	1.40	6.26	40.52	11.92	0.88	14.99	
247–B.	19–1–27	N. Afza 35	19.47	18.53	95.17	0.85	8.93	47.67	14.80	0.61	13.48	
Kinara	30–1–27	,, 23	20.14	12.11	85.75	1.42	6.89	36.92	12.51	0.78	16.62	
Ledu	13–1–27	N. Bagh	15.90	11.02	69.30	2.31	7.89	42.20	....Not	determin	ed....	

*Suitable apparatus was not available for bagasse analysis.

TABLE XIII.

Monthly variations in the constituents of canes grown on field scale.

Variety of cane	Date of analysis	Juice analysis				Bagasse analysis		Cane analysis			Remarks
		Brix	Sucrose %	Purity	R.S. %	Sucrose %	Fibre* %	Sucrose %	R.S. %	Fibre* %	
S.48	November 1926	18.34	14.74	80.30	0.82	6.64	44.20	12.00	0.53	14.57	R. S. denotes Reducing Sugars.
,,	December ,,	19.99	17.30	86.52	0.77	6.96	47.85	13.85	0.52	16.09	
,,	January 1927	20.72	17.99	86.82	0.79	6.81	46.14	14.08	0.53	16.08	
,,	February ,,	22.33	20.19	90.42	0.75	7.55	48.12	15.84	0.49	15.97	
,,	March ,,	21.99	19.20	87.31	0.50	6.62	46.17	15.99	0.33	15.85	
Co. 213	November 1926	17.10	13.13	76.78	1.05	6.22	50.80	10.45	0.68	16.80	
,,	December ,,	18.56	14.82	79.85	1.07	6.22	46.34	11.80	0.85	16.34	
,,	January 1927	20.59	17.11	83.08	0.80	7.48	47.73	13.75	0.54	16.22	
,,	February ,,	22.74	19.74	86.80	0.64	6.11	50.25	15.17	0.40	16.57	
,,	March ,,	22.81	20.96	91.88	0.39	8.54	52.55	17.04	0.26	17.21	
Co. 214	October 1926	18.00	15.03	83.49	..	..	..	..	..	..	
,,	November ,,	21.36	17.99	84.06	1.35	6.89	50.15	14.67	0.90	16.61	
,,	December ,,	21.68	18.55	85.56	0.79	5.93	47.71	14.11	0.51	16.69	
,,	January 1927	21.97	17.51	79.69	0.88	7.85	47.65	14.19	0.58	16.87	

*Suitable apparatus was not available for the analysis of bagasse.

TABLE XIII.—(Concluded)

Monthly Variations in the constituents of canes grown on field Scale.

Variety of cane	Date of analysis	Juice analysis				Bagasse analysis		Cane analysis			Remarks
		Brix	Sucrose %	Purity	R.S. %	Sucrose %	Fibre* %	Sucrose %	R.S %	Fibre* %	
Co. 221	November 1926	19.00	15.04	79.15	1.09	8.94	44.50	12.98	0.72	15.04	R. S. denotes reducing sugars.
,,	December ,,	18.86	16.79	89.02	0.46	5.13	48.25	13.15	0.39	16.40	
,,	January 1927	19.90	18.02	90.55	0.69	7.62	47.47	14.35	0.45	16.19	
,,	February ,,	21.39	19.02	88.92	0.83	7.12	49.78	14.64	0.54	16.68	
,,	March ,,	21.28	18.94	89.03	0.43	5.21	48.57	14.21	0.25	16.68	
Manjav	November 1926	15.02	11.97	79.67	2.22	8.98	37.90	11.06	1.15	10.43	
,,	December ,,	17.89	15.40	86.09	1.23	9.74	..	14.68	0.82	..	
,,	January 1927	18.73	15.43	82.38	1.29	10.50	38.90	13.96	1.25	12.11	
,,	February ,,	20.27	19.10	91.10	0.37	7.18	39.55	15.74	0.26	11.86	
,,	March ,,	21.01	19.23	91.57	0.55	7.78	36.05	14.12	0.35	12.90	
Lakhapur	November 1926	16.00	12.40	77.50	1.58	6.98	39.64	10.76	1.04	12.18	
,,	December ,,	18.76	16.58	88.37	0.79	8.16	39.35	13.96	0.44	12.19	
,,	January 1927	19.97	17.48	87.53	0.73	8.05	37.25	14.69	0.51	11.02	
,,	February ,,	21.24	18.92	89.07	0.58	9.29	34.25	16.03	0.41	10.27	

*Suitable apparatus was not available for the analysis of bagasse.

TABLE XIV.

Average composition of canes grown on field scale (Plant crop).

Variety of cane	Analysis of Juice				Analysis of bagasse		Analysis of Cane			Remarks.
	Brix	Sucrose %	Purity	R. S. %	Sucrose %	Fibre * %	Sucrose %	R. S. %	Fibre * %	
S. 48	20.67	17.88	86.21	0.73	6.91	46.50	14.35	0.48	15.71	R. S. denctes
Co. 213	20.36	17.15	83.66	0.79	6.91	49.53	13.64	0.55	16.63	Reducing Sugars.
Co. 214	20.78	17.27	83.20	1.00	6.89	48.50	14.32	0.66	16.72	
Co. 221	20.08	17.56	87.29	0.70	6.60	47.71	13.86	0.47	16.19	
Manjav	18.42	16.03	86.45	1.23	8.38	38.10	13.72	0.78	11.82	
Lakhapur	18.99	16.34	85.62	0.92	8.12	37.62	13.86	0.60	11.42	

*Suitable apparatus was not available for the analysis of bagasse.

TABLE XV.

Showing actual and probable recovery of sucrose from different varieties of cane grown on field scale.

Variety of cane.	Sucrose in cane. %	Sucrose extracted with bullock power mills. %	Sucrose extracted from 100 of sucrose %	Available sucrose which could be extracted with efficient mills. %	Sucrose lost on 100 of available sucrose. Difference of Cols. 4 and 5 %	Sucrose actually recovered on cane. %	Sucrose which could be recovered if the extraction was as good as shown in Col. 5.	Sucrose lost on account of faulty extraction. Difference of Cols. 7 and 8.
1	2	3	4	5	6	7	8	9
S. 48	14.35	11.80	82.24	90	7.76	8.92	9.76	0.84
Co. 213	13.64	11.32	83.00	90	7.00	8.21	8.90	0.69
Co. 214*	14.32	10.53*	73.53	85	11.47*	7.63*	8.82	1.19
Co. 221	13.86	11.59	83.69	90	6.31	8.47	9.11	0.64
Manjav	13.72	11.70	85.28	91	5.72	8.81	9.40	0.59
Lakhapur † (P.O.J. 33)	13.86	11.90	85.88	91	5.12	7.84	8.31	0.47
Average	13.96	11.48	82.27	89.5	7.23	8.32	9.05	0.74

*Co. 214 is a thin cane and gives an average extraction of 61% juice on cane.

† This year the cane (P.O.J. 33) was attacked by Red Rot otherwise it is an excellent variety.

RATOONS.

Medium and thin canes ratoon very well in heavy Malwa soils but soft and thick canes which have so far been tried do not give very good ratoons.

When medium canes are harvested and the roots together with a portion of the stalk are left in the ground, a profuse tillering takes place and the stool of the former plant crop contains many more canes than it did previously. The canes however become thinner but their number acts as an offset, and the acreage out-turn is almost as good as that of the previous plant crop.

In tables XVI pages 272-274 and XVII pages 275 are given the analytical data of the first ratoon of the imported, exotic and seedling canes grown on field scale. Table XVI pages 272-274 shows that the constituents of the ratoon canes varied not only from field to field but also in different parts of the same field. A comparison of tables XIV and XVII pages 269 and 275 respectively) proves that the first ratoon canes generally contained a little lower percentage of sucrose and a little higher percentage of reducing sugars and of fibre, than was found in plant crop of the same variety of cane grown on field scale. It must however be remembered that ratoon canes ripen earlier than the plant crop and are harvested at a very different period of the year, conditions which probably influence the composition of the ratoon crops.

TABLE XVI.

Analysis of the first Ratoon of canes grown on field scale.

Variety of cane	Date of analysis	Farm & field No.	Juice analysis				Bagasse analysis		Cane analysis			Remarks
			Brix	Sucrose %	Purity	R. S. %	Sucrose %	Fibre * %	Sucrose %	R. S. %	Fibre * %	
S.48	16-11-26	N. Afza 23	17.40	14.49	83.27	1.01	6.89	51.38	11.93	0.55	17.03	
,,	21-11-26	,, ,,	18.00	15.18	84.33	0.89	6.86	51.38	12.27	0.58	17.03	R. S. denotes
,,	4-12-26	,, ,,	19.41	17.60	90.67	0.48	6.91	48.15	13.86	0.40	17.09	Reducing
,,	20-10-26	,, 20	17.50	14.59	83.37	0.67	6.86	48.21	11.99	0.44	16.31	Sugars.
,,	7-12-26	,, ,,	21.44	18.59	86.70	0.47	7.67	47.75	14.59	0.30	17.50	
,,	14-12-26	,, ,,	20.24	18.02	89.00	0.37	9.20	40.45	14.48	0.61	16.24	
,,	28-10-26	N. Bagh 9/2	16.00	13.60	85.00	..	..	..	..	..	..	
,,	31-10-26	,, ,,	17.10	14.40	84.21	..	..	..	..	..	..	
,,	21-1-27	,, ,,	20.10	17.81	88.60	0.46	6.03	47.27	13.53	0.29	17.21	
,,	23-1-27	,, ,,	19.84	17.20	86.69	0.37	6.09	46.75	13.77	0.21	15.56	
,,	25-1-27	,, 5	19.21	17.42	90.68	0.17	6.28	44.52	13.33	0.11	17.30	

* Suitable apparatus was not available for the analysis of bagasse.

TABLE XVI.—(Continued).

Analysis of the first Ratoon of Canes grown on field scale,

Variety of cane	Date of analysis	Farm & field No.	Juice analysis				Bagasse analysis		Cane analysis			Remarks
			Brix	Sucrose %	Purity	R. S. %	Sucrose %	Fibre * %	Sucrose %	R. S. %	Fibre * %	
S. 48	15-2-27	N. Bagh 9/2	24.66	21.46	87.02	0.91	6.63	47.42	14.87	0.50	17.54	
,,	6-2-27	,, Misc.	21.18	17.87	84.37	0.50	8.33	43.75	14.17	0.30	17.06	R. S. denotes
Co. 221	9-1-27	N.Afza 13	19.90	18.02	90.55	0.69	7.62	47.47	14.38	0.45	16.38	Reducing
,,	28-12-26	,, 23	18.86	16.79	89.02	0.46	5.13	48.25	12.71	0.39	16.40	Sugars.
,,	21-10-26	,, 20	18.20	15.01	82.47	1.42	5.38	44.31	13.32	0.88	16.83	
,,	10-1-27	,, ,,	20.57	17.81	86.58	0.58	6.66	44.68	14.02	0.48	15.19	
,,	14-11-26	,, 12	19.00	15.81	83.21	1.42	6.71	46.37	12.52	0.92	16.23	
Co. 221	20-11-26	,, ,,	18.70	15.70	83.96	1.35	8.45	49.75	13.31	0.88	17.12	
,,	8-12-26	,, 25	19.89	16.54	83.16	0.79	8.45	49.80	12.53	0.48	17.43	
,,	11-12-26	,, 15	21.68	18.55	85.56	0.46	5.93	45.75	13.66	0.30	17.55	
Co. 214	15-10-26	,, 12	18.00	15.45	85.83	..	..	..	..	..	..	

*Suitable apparatus was not available for the analysis of bagasse.

TABLE XVI.—(Concluded.).

Analysis of the first Ratoon of Canes grown on field scale.

Variety of cane	Date of analysis	Farm & field No.	Juice analysis				Bagasse analysis		Cane analysis			Remarks
			Brix	Sucrose %	Purity	R. S. %	Sucrose %	Fibre * %	Sucrose %	R. S. %	Fibre * %	
Co. 214	17-10-26	12	18.10	15.58	86.07	1.20	6.83	48.20	12.08	0.82	16.72	
,,	30-11-26	,,	21.48	18.84	87.70	0.98	6.88	50.60	13.46	0.78	17.10	R. S. denotes Reducing Sugars.
,,	4-12-26	,,	23.92	21.00	87.79	0.67	7.21	51.99	14.79	0.40	19.20	
,,	1-1-27	,,	22.83	19.22	84.18	0.81	6.92	52.00	14.89	0.49	19.23	
Manjav	19-10-26	N. Afza 6	15.20	12.23	80.46	1.30	7.88	37.75	10.92	0.87	11.33	
,,	20-11-26	,, ,,	17.70	13.61	76.89	1.56	8.37	41.38	11.96	1.09	13.37	
,,	9-12-26	,, ,,	17.60	14.79	84.03	0.79	8.03	37.90	11.28	0.62	13.51	
,,	19-1-27	,, 12	19.90	14.90	74.87	1.23	8.53	42.15	12.90	0.81	13.49	
P.O.J.33	16-11-26	,, ,,	20.00	17.14	85.70	1.35	7.38	40.24	14.02	0.92	14.10	
,,	9-12-26	,, ,,	19.65	17.05	86.76	0.80	7.18	41.05	14.60	0.49	14.36	
,,	12-1-27	N.B. 8/3	19.20	16.43	85.58	1.11	7.28	47.43	13.41	0.74	15.05	
,,	19-1-27	N.Afza 20	20.40	17.60	86.27	1.18	8.97	46.15	14.23	0.84	14.84	

*Suitable apparatus was not available for the analysis of bagasse.

TABLE XVII.

Average composition of first Ratoon of canes grown on field scale.

Variety of cane	Analysis of juice				Analysis of bagasse		Analysis of cane			Remarks.
	Brix	Sucrose %	Purity	Reducing Sugars %	Sucrose %	Fibre %	Sucrose %	Reducing Sugars %	Fibre * %	
S.48	19.95	17.29	86.66	0.55	7.07	47.01	13.53	0.38	16.90	R. S. denotes
Co. 214	20.87	18.02	86.40	0.92	6.96	51.36	13.56	0.62	18.06	Reducing Sugars.
Co. 221	19.60	16.78	85.57	0.89	6.79	47.05	13.31	0.60	16.64	
Manjav	17.60	13.88	79.47	1.22	8.20	39.80	11.76	0.85	12.93	
Lakhapur (P.O.J. 33)	19.81	17.06	86.08	1.11	7.70	43.97	14.07	0.75	14.59	

*Suitable apparatus was not available for the analysis of bagasse.

Massecuites.

The precautions which from a chemical point of view have to be taken in the preparation of good quality massecuites have been discussed in the previous pages. The final recovery of sugar however depends more upon the amount of sucrose and the size of the grains which crystallise out on cooling the massecuite. This phenomenon in its turn is governed by the chemical laws enumerated below :—

(1) The larger the quantity of water present, within certain limits, the larger will be the size of the grains but the smaller will be the amount of sucrose which crystallises out of such a massecuite. Conversely, the smaller the amount of water present in the final massecuite, the larger will be the amount of sucrose which crystallises out of such a solution, but the smaller will be the size of the grain. In other words the crystallisation of sucrose from a supersaturated solution of sucrose in water is inversely proportional to the amount of water present, and the size of the grain, within certain limits, is directly proportional to the quantity of water present in the final massecuite. It must however be remembered that for the formation of sugar crystals a liquid medium is absolutely essential. All the water cannot therefore be boiled out in actual practice. Furthermore sugar itself contains hydrogen and oxygen in the proportion in which they combine to form the molecules of water. If therefore an attempt were to be made to remove all of it, the sucrose molecules would begin to loose their own water and ultimately decompose into carbon dioxide and water, especially in the open pan system of boiling, where the temperature of the boiling syrup is very high.

$$C_{12}H_{22}O_{11} + 12O_2 \xrightarrow{\text{heat}} 12CO_2 + 11H_2O$$

(2) Other things remaining the same, the greater the amount of impurities and salts, specially the positive molasses-forming† salts, the greater will be the amount of sucrose which remains in solution after the massecuite has been boiled to its final consistency and the slower will be the rate of crystallisation.

In this connection Degener, *found that the lowest solubilities of salt and sucrose in solutions of these two in water correspond with the formulae of $NaCl + 4C_{12}H_{22}O_{11}$ for the sodium chloride combination, and with $CaCl_2 + 3C_{12}H_{22}O_{11}$ for the corresponding calcium chloride combination; whereas the solubility of sucrose

---

† When much of salt and sugar combined are soluble in water such a salt is called positive molasses-former. When the combination is slightly soluble such a salt is called negative molasses-former.

*"Deutsche Zukerindustrie," 20,2149.

in water of the pure molasses is a little over two parts of sucrose to one part of water, and differs with the variation of the percentage of invert sugar present in the mass containing the molasses.

It is therefore very important not to introduce large quantities of positive molasses-forming salts in the course of defecation or in any other way, as there will then be a sucrose-salt-water combination and much of the recoverable sugar would thereby be lost.

(3) The rate of crystallisation and the size of the grain are greatly influenced by the rate of cooling. If the temperature of the cooling mass is rapidly brought down, the sugar in solution crystallises out instantaneously into very small crystals. These minute crystals form an emulsion with the molasses, giving it a turbid appearance, which firmly adheres to the large crystals and can be only removed by copious washing with water, while the tiny crystals in emulsion with the molasses pass out through the the centrifugal mesh. The surfaces of the larger crystals are also dissolved in the water and increase the loss. Finally, the molasses obtained is thereby diluted and this water has to be evaporated in the preparation of the second massecuites, a feature which will cause the loss of recoverable sugar on account of undue inversion brought about by having to keep the pan longer on the boiling furnace. Hence a slow fall of temperature is absolutely essential when cooling the massecuites prepared by open-pan system of boiling. In fact this was abundantly proved by several experiments carried out at the Research Station for the preparation of large sized grain. The boiler after striking the pan did not air the mass but potted it in a container,which was later covered tightly with pieces of gunny bags, etc., and the open spaces between the lid and the container were plastered with sticky mud. After 48 hours or more when the container was opened the sugar in solution had crystallised out into big beautiful crystals.

The main defect of the system however lies in the fact that the pan has to be struck at a temperature of about 108°c to 109°c leaving thereby a large amount of water in the boiled mass which keeps a good deal of sugar in solution. The final recovery of sugar is not, therefore, very high.

To avoid losses in this way and at the same time to be able to get good medium-sized grain with a high final recovery, crystallisation-in-motion, which also ensures even fall in temperature, is recommended.

Oscillation, while slow cooling is going on, helps the formation of bigger and better grain, as it gives the crystals free space to move in every direction.

Tables XVIII and XIX give the average composition, for the season, of the massecuites of canes grown on field scale and show that the recovery of first sugar on cane was actually governed by the factors discussed above.

TABLE XVIII.

Composition of the first massecuites of plant crops grown on field scale.

Variety. of cane.	Total solids %	Sucrose %	Reducing Sugars %	Moisture. %	Ash %	Purity.	Sugar (first) on cane. %
S. 48	92.11	78.02	7.85	7.89	2.23	84.70	6.40
Co. 213	92.21	76.08	8.95	7.79	2.36	82.51	6.20
Co. 214	92.50	74.35	9.25	7.50	2.65	80.38	5.74
Co. 221	92.22	77.21	8.12	7.78	2.34	83.72	6.25
Manjav	92.35	77.19	8.85	7.65	2.16	83.58	5.94
Lakhapur (P.O.J. 33)	92.40	74.81	9.21	7.60	2.38	80.96	6.09

TABLE XIX.

Composition of the first massecuites of ratoons grown on field scale.

Variety of cane	Total solids. %	Sucrose %	Reducing Sugars %	Moisture. %	Ash %	Purity	Sugar (1st) on cane. %
S. 48	92.08	76.21	7.92	7.92	2.31	82.73	6.26
Co. 221	92.19	76.18	8.21	7.81	2.42	82.63	6.26
Manjav	90.66	74.12	8.47	9.34	2.51	81.72	5.70
Lakhapur (P.O.J. 33)	91.65	75.12	8.17	8.35	2.47	81.96	5.85

The massecuites of S. 48 contained the lowest percentage of salts and invert sugar and the highest purity, yielding also the highest percentage of sugar on cane, whereas the massecuite of Co. 214 in table XVIII contained the highest percentage of reducing sugars and salt and had the lowest purity, yielding consequently the lowest percentage of first sugar. Similarly the massecuite of Manjav in table XIX had the highest percentage

of reducing sugars, moisture and salts and consequently yielded the lowest percentage of sugar on cane. The high percentage of ash in massecuites is to some extent due to the boiling and crushing having had to be carried on in an open place which caused dirt and silicious matter to become mixed up with the raw juice and the boiling syrup.

Second Massecuites.

Maximum care should always be taken in the boiling of the second massecuites. The phenomenon technically called "froth fermentation" or **gobh** in India is a common feature when low-grade molasses are boiled. It is probably caused by the spontaneous decomposition of products formed by previous decomposition of sucrose or reducing sugars forming carbonic, formic and acetic acids and caramel. The best way to prevent this, as much as possible, is to skim copiously the boiling inferior molasses to remove all the undesirable compounds present. If this precaution is taken during the course of boiling, then there is little likelihood of the final massecuite from inferior molasses frothing over the containers in which it is potted—a thing very common in open pan boiled massecuites from inferior molasses.

When the above precautions have been taken and yet frothing takes place, then the next best thing to do is to remove all the froth from the containers, which ensures almost complete crystallisation of the sugar in the second massecuite, and also stops further formation of decomposition products, which is caused by the rise in the temperature of the mass in the container when frothing is going on.

If the second massecuite is viscous as is generally the case when prepared from inferior molasses, then it would be advisable to cure it during the hot summer months.

The main reasons for this suggestion are that the viscosity of sucrose solutions increases with the increase in concentration and decreases with the rise in temperature. In fact the decrease in viscosity with the rise in temperature is much more considerable than its increase by the higher concentration.

In table XX and XXI are given the analytical data of second massecuites which again confirm the previous discussion.

TABLE XX.

Composition of the second massecuites of plant crops grown on field scale.

Variety of Cane.	Total solids. %	Sucrose %	Reducing Sugars %	Moisture. %	Ash. %	Purity	Sugar (2nd) on cane %
S. 48	89.73	58.93	14.21	10.27	5.21	65.67	2.54
Co. 213	87.29	56.71	15.78	12.71	5.82	64.97	2.08
Co. 214	87.09	52.31	17.82	12.91	5.76	60.06	1.88
Co. 221	87.57	56.21	16.12	12.43	6.31	64.19	2.08
Manjav	87.88	57.92	16.11	12.12	5.71	65.91	2.21
Lakhapur (P.O.J. 33)	86.79	53.28	17.71	13.21	5.91	61.39	1.92

TABLE XXI.

Composition of the second massecuite of ratoon canes grown on field scale.

Variety of Cane.	Total solids. %	Sucrose %	Reducing Sugars %	Moisture %	Ash. %	Purity	Sugar (2nd) on cane %
S. 48	88.73	56.20	15.35	11.27	5.35	63.34	2 34
Co. 221	88.03	55.19	15.82	11.97	5.61	62.69	
Manjav	87.62	50.03	17.81	12.38	6.71	57.09	1.05
Lakhapur (P.O.J.33)	86.81	52.71	16.12	13.19	5.73	60.72	2.19

Sugars.

Polarisation of first sugars varied from 99.28 to 97.75 giving an average of 98.51, while that of second sugars varied from 97.36 to 96.41 giving an average of 96.88.

TABLE XXII.

Polarisation of Sugars.

Kind of sugar	Quality	Polarisation.
1st sugar	A	99.28
1st sugar	B	97.75
2nd sugar	A	97.36
2nd sugar	B	96.41
Qand or refined sugar	A	99.80
Misri or sugarcandy	A	99.78

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1. W. H. Th. Harloff & H. Schmidt—Plantation White Sugar Manufacture.

2. B. Viswanath & S. Kasinatha Ayyar—Studies in the Chemistry, of Sugarcane, 11 Memoirs of the Dept. of Agric. India, Volume VII, No. 6.

3. T. S. Venkatraman & Krishnamurti Row—Study of the Sucrose Variation in successive cane joints as they attain maturity with reference to the death of the leaves. The Agric. Journal of India, Special Indian Science Congress No., 1917.

4. B. Viswanath—Studies in the Chemistry of Sugarcane. The Agric. Journal of India, Vol. 14 Part III. 1919.

5. H. C. Prinsen Geerligs—Cane Sugar and Its Manufacture.

6. Noel Deerr—Cane Sugar. 1921

Slide Rule and Logarithmic Tables have been used in making calculations contained in the tables of Chemical Notes for 1925-26 and 1926-27.

CHAPTER XVIII.

Distribution of the original Sucrose content (Seasons 1924-25 and 1925–1926.)

The records of yields obtained by the various operations and the analytical information furnished by the chemists associated in the research can be summarised in terms of the sucrose content of the juice or of the original cane and so provide figures from which a graphical representation can be made of the distribution of the sucrose and final products, or as waste material and the loss sustained by the operations. Such graphical representations are very instructive; the whole circle represents the original sugar content present, and the various sectors represent the relative proportions of that same sugar as found in different forms, when the work is done.

The graphs are self-explanatory and the figures from which they are constructed, having been developed in the text of the book, require no explanation, except that they all refer to the sucrose in 100 lbs. of cane in Diagram I. and to the sucrose in 100 lbs. of juice in Diagram 2.

Research Season 1924–1925.
Sugar per 100 lbs. cane for Diagram 1

			Total Sucrose in lbs.
100 lbs cane.	.. @ 14.52% Sucrose	=	14.52
67 lbs. juice	... @ 18.56% Sucrose	= 12.44	14.47
33 lbs. bagasse	.. @ 6.14% Sucrose	= 2.03	
	Loss during milling and storage		0.05
14.07 lbs. rab. ..	@ 80.68% Sucrose	= 11.35	
	Loss by inversion during first boil. (difference between 12.44 and 11.35)		1.09
6.55 lbs first sugar	.. @ 96.0% Sucrose	= 6.30	10.62
7.52 lbs. first molasses	.. @ 57.2% Sucrose	= 4.32	
	Loss unaccounted for	=	0.73
2.4 lbs. second sugar	@88.7% Sucrose	= 2.13	3.50
3.79 lbs. second molasses	@35.7% Sucrose	= 1.37	

DIAGRAM 1.

DISTRIBUTION OF SUCROSE ORIGINALLY PRESENT IN CANE

SEASON 1924-25.

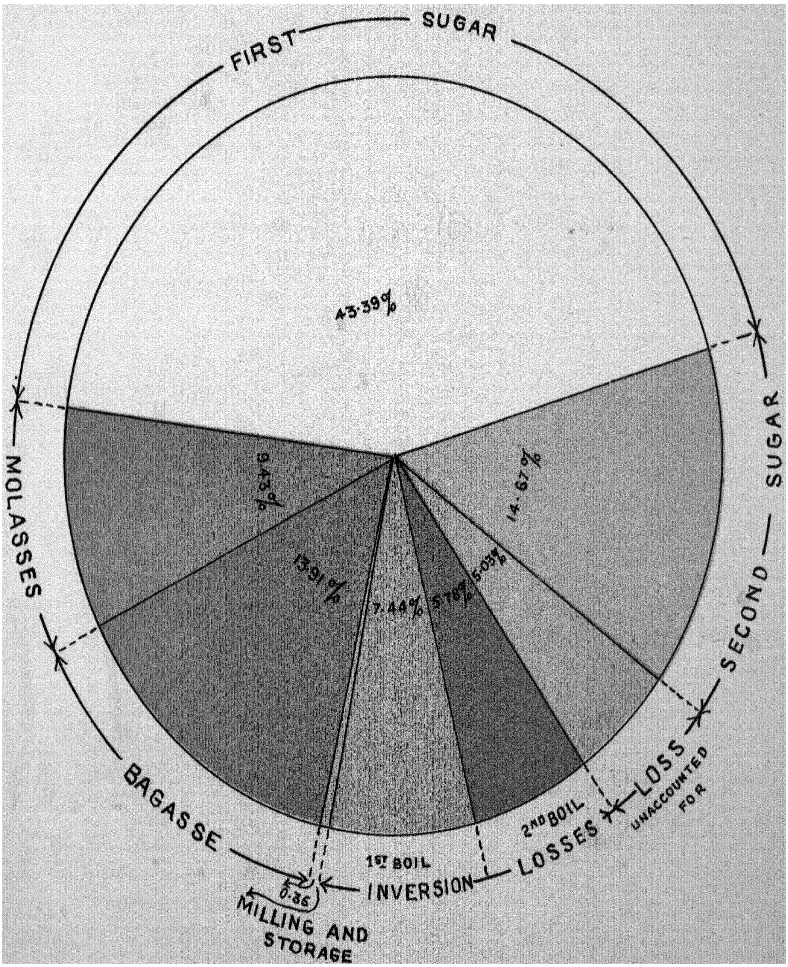
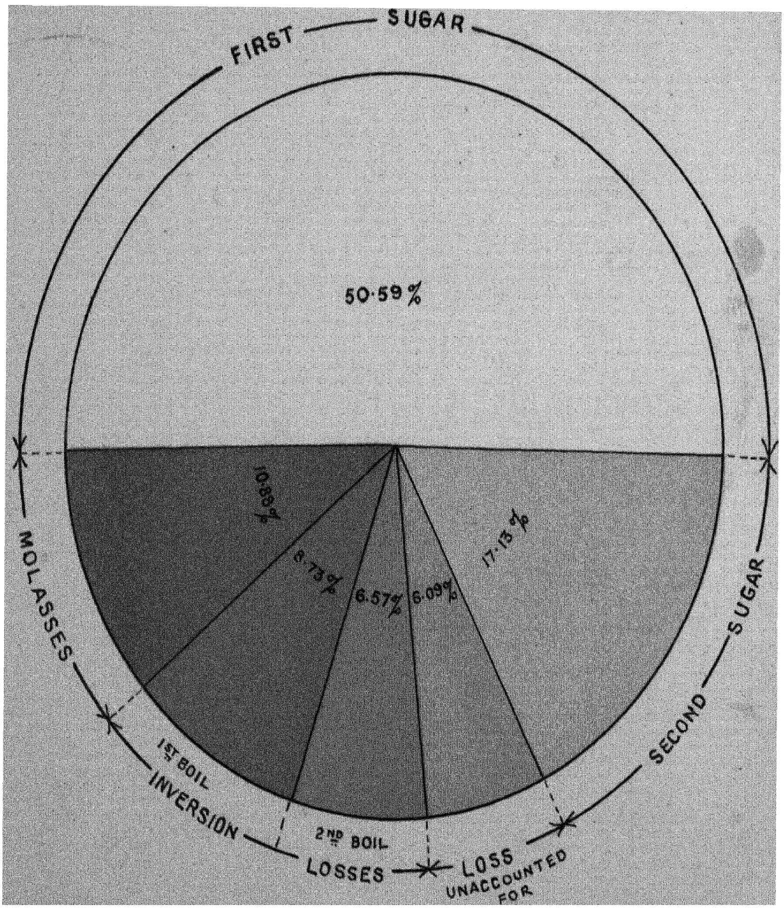


DIAGRAM 2.

Distribution of Sucrose Originally Present in Juice

Season 1924-25.



Loss by inversion during second boil = 0.82
(difference between 4.32 and 3.50)

Then leaving out all the intermediate figures the proportions are:—

	lbs.	%	In terms of Circular degrees
Sucrose in cane	14.52	100	360
Sucrose in 6.55 lbs. of first sugar	6.30	43.39	156.2
,, ,, 2.4 lbs. second sugar	2.13	14.67	52.8
,, ,, 3.79 lbs. molasses	1.37	9.43	33.9
,, ,, 33 lbs. Bagasse	2.03	13.91	50.1
Loss during milling & storage	0.05	0.35	1.3
,, by inversion at first boil	1.09	7.44	26.8
,, ,, ,, second boil	0.82	5.78	20.8
,, unaccounted for	0.73	5.03	18.1
	14.52	100.00	360.0

Research Season 1924-25.

Sugar per 100 lbs juice for Diagram 2

Total sucrose in lbs.

100 lbs. juice .. @18.56 Sucrose = 18.56

21 lbs. rab. ... @80.68% Sucrose = 16.94

Loss by inversion during first boil = 1.62

9.78 lbs. first sugar .. @96.0% Sucrose = 9.39

11.22 lbs. first molasses @57.2% Sucrose = 6.42

(9.39 + 6.42) = 15.81

Loss unaccounted for = 1.13

3.58 lbs. second sugar .. @88.7% Sucrose = 3.18

5.66 lbs. second molasses .. @35.7% Sucrose = 2.02

(3.18 + 2.02) = 5.20

Loss by inversion during second boil = 1.22

Then leaving out the intermediate figures the proportions are:—

	lbs.	%	In terms of circular degrees
Sucrose in juice	18.56	100	360
Sucrose in 9.78 lbs. of first sugar	9.39	50.59	182.1
„ „ 3.58 „ second sugar	3.18	17.14	61.7
„ „ 5.66 lbs. of molasses	2.02	10.88	39.2
Loss by inversion during first boil	1.62	8.73	31.4
„ „ „ „ second boil	1.22	6.57	23.7
Loss unaccounted for	1.13	6.09	21.9
	18.56	100.00	360.0

Research Season 1925-26.

Sugar per 100 lbs. of cane for Diagram 1.

Total Sucrose in lbs.

100 lbs cane .. @ 14.6% Sucrose = 14.6

70 lbs. juice .. @ 18.15% Sucrose = 12.71

30 lbs. bagasse .. .. @6.10% Sucrose = 1.83 } = 14.54

Loss in milling & storage 0.06

14.17 lbs. **rab** .. @ 82.6% Sucrose - 11.70

Loss by inversion during 1st boil = 1.01

7.30 lbs. first sugar .. @ 97 % Sucrose = 7.08

6.87 lbs. First Molasses .. @ 57 % Sucrose = 3.92 } = 11.00

Loss unaccounted for = 0.70

1.99 lbs. second sugar .. @ 94 % Sucrose = 1.87

3.37 lbs. Second Molasses @ 36.65% Sucrose = 1.24 } = 3.11

Loss by inversion during second boil = 0.81

DIAGRAM 1.

DISTRIBUTION OF SUCROSE ORIGINALLY PRESENT IN CANE

SEASON 1925-26.

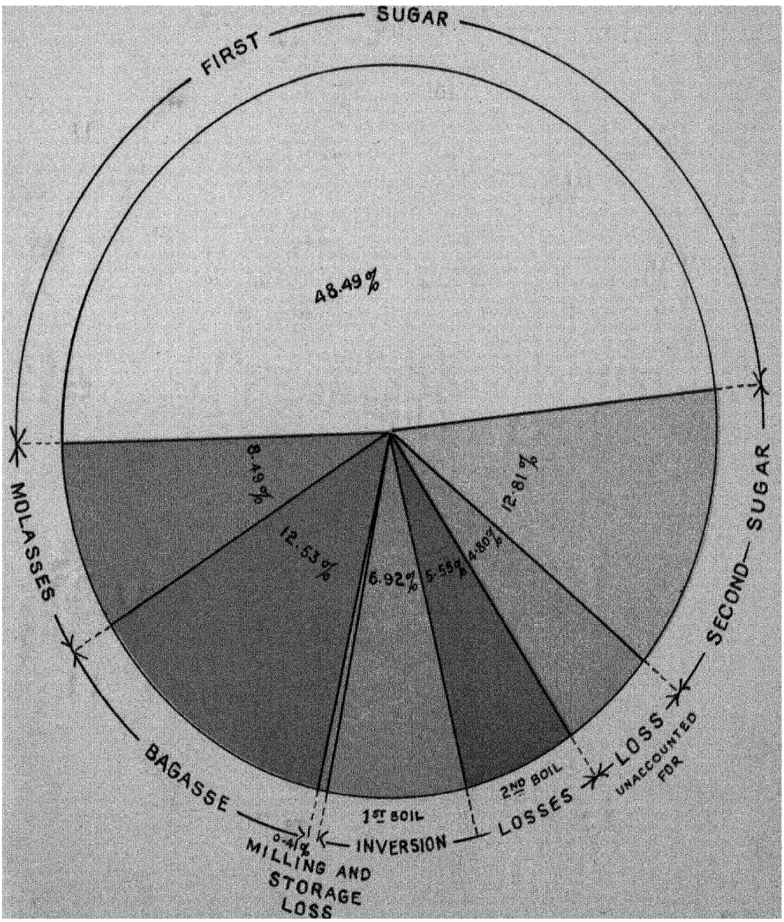
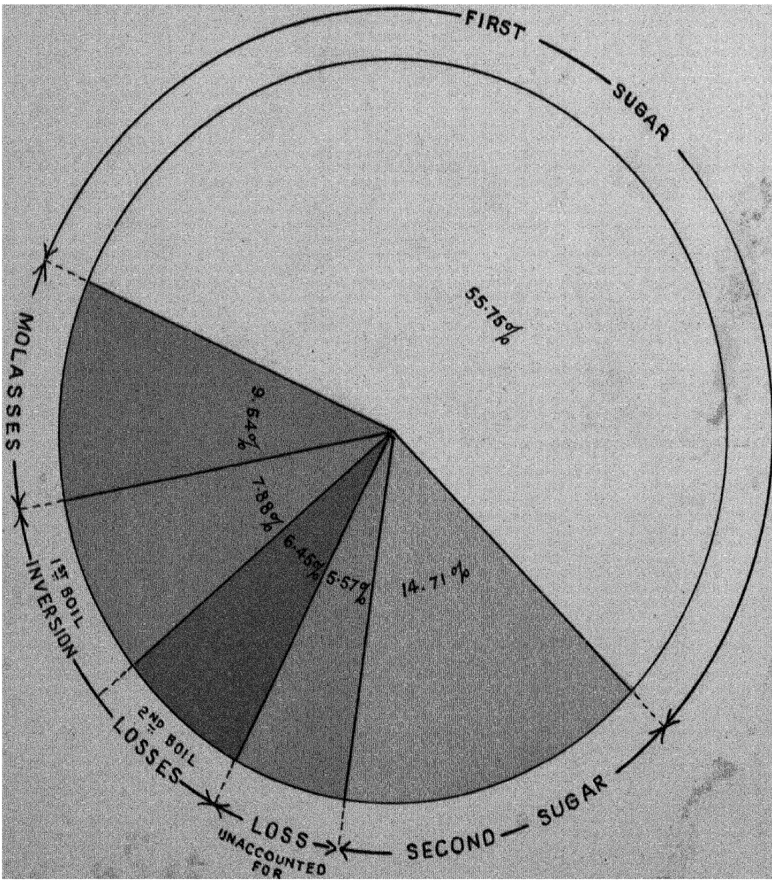


DIAGRAM 2.

DISTRIBUTION OF SUCROSE ORIGINALLY PRESENT IN JUICE

SEASON 1925-26.



Then leaving out all the intermediate figures the proportions are:—

	lbs.	%	In terms of Circular degrees
Sucrose in cane	14.6	100	360
Sucrose in 7.30 lbs. of first sugar	7.08	48.49	174.6
„ „ 1.99 lbs. of second sugar	1.87	12.81	46.1
„ „ 3.37 lbs. of molasses	1.24	8.49	30.6
„ „ 30.00 lbs. of bagasse	1.83	12.53	45.1
Loss during milling and storage	0.06	0.41	1.5
„ by inversion during first boil	1.01	6.92	24.9
„ „ „ „ second boil	0.81	5.55	19.9
„ Unaccounted for	0.70	4.80	17.3
	14.60	100.00	360.0

Research Season 1925-26.

Sugar per 100 lbs. juice for Diagram 2.

Total sucrose in lbs.

100 lbs. juice ..@ 18.15% Sucrose = 18.15

20.24 lbs. **rab.** @ 82.60% Sucrose = 16.72

Loss by inversion during first boil = 1.43

10.43 lbs. first sugar .. @ 97.00% Sucrose = 10.12

= 15.71

19.81 lbs. first molasses @ 57.00% Sucrose = 5.59

Loss unaccounted for = 1.01

2.84 lbs. second sugar .. @ 94.00% Sucrose = 2.67

= 4.42

4.81 lbs. second molasses @ 36.65% Sucrose = 1.75

Loss by inversion during second boil = 1.17

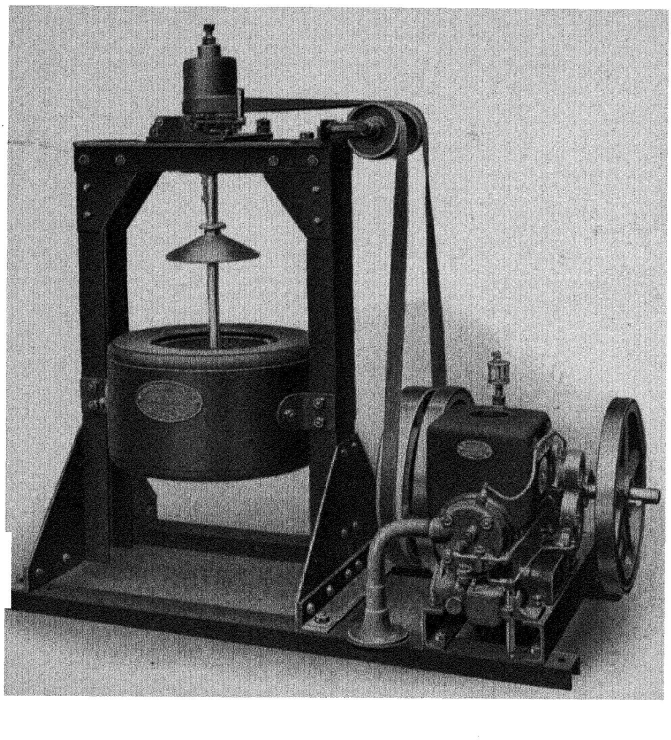
Then leaving out all the intermediate figures the proportions are:—

	lbs.	%	In terms of Circular degrees
Sucrose in juice	18.15	100	360
„ „ 10.43 lbs first sugar	10.12	55.75	200.70
„ „ 2.84 lbs second „	2.67	14.71	52.99
„ „ 4.81 lbs molasses	1.75	9.64	34.70
Loss by inversion during first boil	1.43	7.88	28.37
„ „ „ „ second boil	1.17	6.45	23.22
Loss unaccounted for	1.01	5.57	20.05
	18.15	100.00	360.0

18-in. CENTRIFUGAL

DRIVEN BY A

$2\frac{1}{2}$ B.H.P. "Ruston" Oil Engine.



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APPENDIX A.

In course of the progress of experiments with the various hand-power centrifugals it had been realised both by the author and the Huddersfield Firm, that a substantial reduction in the cost of curing the sugar was highly desirable, an object which could only be secured by substituting hand labour by mechanical power, which was decidedly cheaper and far more efficient. Continuous rise in wages in all parts of India was another reason which rendered such a change necessary. Besides it had been found that constant supervision was essential throughout the day in order to exact enough efficient work out of the team employed for working the hand centrifugal and even then the quality of the outturn was not uniform owing to the difficulty of maintaining the requisite speed of the machine throughout the working period.

After this book had gone to the press Messrs Thomas Broadbent & Sons brought out to India a centrifugal of 18″ diameter combined with a 2½ Horse-Power Ruston & Hornsby's class P. R. Petrol-paraffin Engine (Type 17B) illustrated on the opposite page. This centrifugal which was fully tested by the author at Bhopal during the sugar-making season of 1928, gave entire satisfaction. The makers have employed very great mechanical skill in perfecting this particular machine and the author expects a great future for it in the Indian village industry to which it can confidently be recommended, in preference to hand power centrifugals, where the manufacturer can afford to invest an extra initial outlay of Rs. 400/- or 500/- as compared with a hand-power installation.

This little power-driven machine works up easily about 21 Standard Maunds of first or 19 Standard Maunds of second massecuite in a working day of 10 hours into sugar, at a cost of nearly 4 annas per maund of first and about 4¼ annas per maund of second massecuite, the consumption of kerosene oil being nearly 1 lb., of petrol about 1¼ oz., and of mobil oil nearly 1 oz. per hour. The machine conveniently holds a charge of 50 to 56 lbs. at a time, according to the richness and consistency of the **rab**, and is capable of holding heavier charges, but about 50 lbs. which is a good average should not be exceeded, if quality of sugar is the main consideration. This machine should always be loaded while at rest. If charged while running at full speed, as is permissible in the case of hand-power centrifugals, part of the **rab** is liable in rising up to stick to the top of the cage (where there are no perforations and thus to remain uncured) on account of the

great rapidity of speed which in the case of the new power-machine is usually somewhere between 2,000 and 2,100 revolutions per minute instead of 1,800—a speed which the hand centrifugal seldom attains at the start and never maintains throughout the spinning operation. The power machine on the other hand runs uniformly at not less than 2,000 revolutions per minute and the resulting sugar is consequently a product of very superior grade provided the **rab** was of the standard quality.

Compared with hand-power there is a distinct saving of nearly 4 annas per standard maund of **rab** in using the power-machine.

Assuming 2,000 Standard Maunds to be the average quantity dealt with by the manufacturer in an ordinary working season the saving due to the use of the power machine as compared with the hand centrifugal, calculates to Rs. 500/- which more than covers the additional outlay on the power installation.

There are also the additional advantages of the saving of the trouble of attention and of supervision together with a better quality of yield and a larger daily output.

TRIAL OF BROADBENT'S MULTIPLE CRUSHER.

Messrs Thomas Broadbent & Sons of Huddersfield; England, placed on the Indian market in the season 1927-28 a new Multiple Power Cane Crusher composed of two 3-roller mills worked by a 10 B. H. P. Blackstone Oil Engine. In the first mill the size of the rollers which work horizontally is 15″×9″ and in the 2nd. which is placed in front of the first mill the rollers are 12″×9″ Both the mills are worked simultaneously with the engine by means of an arrangement of shafting and pulleys driven by the engine. The total cost of the plant delivered at Bhopal (exclusive of fitting charges) is about Rs. 5,500-.

The cane is bruised in the first set of rollers and the bruised cane is then made to pass automatically through the second set in which it is finally crushed, the juice being collected at two places in iron tanks fixed in the ground or pumped direct to the boiling plant by means of a suitable juice pump and a galvanised iron channel.

To determine the working capacity of the above multiple crusher a number of trials were made during the past season with different varieties of soft thick and hard medium canes for periods varying from a few minutes to over 16 working hours.

With soft thick canes, P. O. J. 33 and the Manjav, an average extraction of 69 p.c. of juice on the cane was generally secured as with the best bullock-power iron mills having 3 rollers working vertically, but the quantities of these varieties available were insufficient to work the mill for a number of hours in order to determine other factors such as the quantity of cane crushed per hour, the oil consumed, the cost incurred etc.

With medium canes which are fairly hard, the ratoon canes being more so than the "plant" canes, it was possible to make long trials only towards the end of the season when the crops were either fully ripe or over-ripe and the canes had in several cases to be carted to the factory a distance of several miles, one to 3 days after they were cut, and had thus lost part of their moisture. It was impossible therefore to obtain the ideal extraction in protracted trials. The maximum extraction of 64 p.c. and an average extraction of nearly 60 p.c. were however obtained under the above conditions. It is that when the rollers were tightened the extraction rose quite appreciably (about 3 p.c.) but the quantity crushed per hour fell from 16 maunds to 10 maunds per hour. The results go to show that in ordinary working the mill may be expected to crush about 16 Standard Maunds of hard cane per hour yielding from 60 to 64 p.c. juice or more according to the richness of the cane and the degree of maturity, consuming 3.92 lbs. of kerosene and 0.78 lb. of lubricating oil per hour, at a total cost, including depreciation, of about 1.36 annas per maund of cane crushed, against 2.14 annas per maund, the cost usually incurred in crushing cane with superior 3-roller iron mills worked by strong bullocks.

It may be observed that no 3-roller or 6-roller power mill hitherto known to the writer can beat the best 3-roller bullock power mill in the matter of extraction, mainly for the reason that in bullock mills nearly all the extractable juice trickles down by gravitation to the receptacle placed at the foot of the mill because of the vertical position of the rollers, while a certain quantity, small thought it is, is always inevitably lost when the rollers are placed horizontally as is the case with the power-mill under consideration, by leakage with the bagasse at the end where the latter is finally discharged by the crushing plant. This is the reason why multiple crushers consisting of several sets of rollers are used when the aim is to obtain higher extraction.

APPENDIX.—(concluded.)

The main advantage of Broadbent's multiple mill is the saving of time besides substantial saving in the cost of crushing which enables the manufacturer to command more *fresh* juice in a given time for boiling, the freshness of the juice causing substantial increase in the yield of sugar.

It would take at least 9 bullock mills to crush in a day the quantity of cane crushed by Broadbent's multiple crusher which may be put down at 194 Standard Maunds.

The cost of crushing 194 maunds of cane with 9 bullock mills in a day will be.................................Rs. 26/-.

That of crushing the same quantity with the multiple mill amounts to...Rs. 17/-.

The saving in the cost of crushing calculates to Rs. 9/- per day.

Assuming that each bullock mill extracts 65 p.c. or in other words 1 p.c. more juice than the power mill (as actual tests have shown) the loss of juice in working the power mill may be estimated at not more than two maunds of juice per day, the price of which should not exceed Rs. 2/-.

Deducting Rs. 2/- from the saving of Rs. 9/- mentioned above the net gain to the manufacturer calculates to Rs. 7/- per day which is a sufficient recommendation for the adoption of the power mill where a manufacturer has to work on a larger scale than is at present the rule in the Rohelkhand village Industry.

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